INJURY, SURVIVAL AND GROWTH OF RAINBOW TROUT CAPTURED BY ELECTROFISHING

By

Thomas T. Taube

RECOMMENDED:

____

____

____
Advisory Committee Chair

APPROVED:

____
Dean, School of Fisheries and Ocean Sciences

____
Dean of the Graduate School

5/1/92
Date

INJURY, SURVIVAL AND GROWTH OF RAINBOW TROUT CAPTURED BY ELECTROFISHING

A

THESIS

Presented to the Faculty

of the University of Alaska Fairbanks

in Partial Fulfillment of the Requirements

for the Degree of

MASTER OF SCIENCE

By

Thomas Theodore Taube, B.S.

Fairbanks, Alaska

May 1992

Abstract

Electrofishing injury studies in Arizona and Alaska revealed spinal injury rates of over 50% among large (>300 mm long) rainbow trout *Oncorhynchus mykiss* captured by electrofishing with pulsed direct current (PDC). My goal was to identify an alternative waveform that would efficiently capture large rainbow trout with injury rates less than 15%. Experiments in homogeneous and heterogeneous electrical fields tested six waveforms; lower injury rates resulted with DC (17%), CPS™ (8%), and 20-Hz PDC at 75% duty cycle (25%). In field experiments with these three waveforms, PDC and DC gave higher capture rates than CPS™. However, injury rate was 60% with 20-Hz PDC and highly variable (0-47%) with DC. Long-term mortality of rainbow trout shocked with 60-Hz PDC at 50% duty cycle was 35% after 203 days. I recommend DC as an alternative to PDC waveforms for relatively safe and efficient capture of large rainbow trout.

Table of Contents

List of Figures

List of Figures (continued)

List of Tables

List of Appendix Tables

Acknowledgments

This study was funded by the Division of Sportfish, Alaska Department of Fish and Game (ADFG) through the Alaska Cooperative Fish and Wildlife Research Unit, University of Alaska Fairbanks. I thank those who made this study a success, particularly Dr. James Reynolds, whose advice on study design and knowledge of electrofishing was invaluable; Don Roach, whose assistance, input, and companionship made project completion possible; and my committee members, Dr. John D. Fox, Dr. Kenneth Kokjer (UAF), and Douglas McBride (ADFG), for their guidance and assistance.

I thank Irv Brock, Carmen Olito, Gary Wall and the staff of the Fort Richardson hatchery (ADFG) for their help and access to facilities and fish for the controlled experiments; John Clark (ADFG) for the use of an electrofishing boat during the field trials; Doug McBride, Dave Rutz, Jim Whitt, Larry Erie (ADFG), and Dave Watsjold (U.S. Fish and Wildlife Service) who assisted in the field trials; and Dr. Ed Murphy (UAF) for guidance in data analysis. Thanks to my fellow graduate students and office mates who have put up with me for over the past two years; their friendship has made the rough times more tolerable. A special thanks to all family and friends who have supported me during this time.

Introduction

Electrofishing is a method commonly used for the capture of rainbow trout *Oncorhynchus mykiss* in population studies. However, reports of spinal injury, internal hemorrhage, mortality, and effects on growth and physiology of electroshocked rainbow trout appear in the literature. As early as 1949, Hauck (1949) reported 26% mortality rate among large rainbow trout captured with alternating current. Injury rates up to 8% and mortality rates from 2 to 11% have been reported in yearling rainbow trout up to 200 mm long (Pratt 1954; McCrimmon and Bidgood 1965; Horak and Klein 1967; Maxfield et al. 1971; Hudy 1985). Short-term mortality rates up to 14% have been reported for large rainbow trout captured with pulsed direct current (Holmes et al. 1990). Growth of rainbow trout exposed once to electrical waveforms was normal (Maxfield et al. 1971; Kynard and Lonsdale 1975), but instantaneous growth rate in rainbow trout electroshocked more than once within a 12 month period was significantly reduced (Gatz et al. 1986). Studies have also reported behavioral and physiological changes in trout captured by electrofishing (Schreck et al. 1976; Bouck and Ball 1966; Woodward and Strange 1987; Mesa and Schreck 1989).

Sharber and Carothers (1988) reported spinal injury rates between 44-67% in large rainbow trout (mean length=360 mm) captured with three forms of pulsed direct current. These injury results caused concern and precipitated a similar study by the Alaska Department of Fish and Game (ADFG) in 1988 on the Kenai River (Holmes et al. 1990). They found 41% spinal injury and 14% short-term (96 hours) mortality in rainbow trout captured with pulsed direct current. A self-imposed moratorium on electrofishing for rainbow trout in Alaska was established by the ADFG. These events led to the development and funding of this project in cooperation with the ADFG; its purpose was to identify electrical waveforms that caused low injury without significant loss in catch efficiency.

This study focused on internal injury (spinal damage and internal hemorrhage), long-term mortality, and growth of large (>300mm) rainbow trout exposed to various waveforms used in electrofishing. The objectives of this study were to estimate internal injury rates caused by various waveforms; to evaluate the effects of electroshock on long-term survival and growth of shocked and injured rainbow trout; and to confirm the results of the first objective in a field test of the low-injury waveforms. These objectives were achieved through three experiments: (1) a controlled study of injury and mortality; (2) a controlled study of long-term mortality and growth; and (3) a field test of injury, short-term mortality, and catch rates.

Methods

The methods of this study were reviewed and approved by the Institutional Animal Care and Use Committee, University of Alaska Fairbanks. The controlled experiments were conducted at the Fort Richardson Hatchery in Anchorage, Alaska. Large rainbow trout (>300 mm) were always used because larger fish are more susceptible to electrofishing than smaller fish (Sullivan 1956) and injury to large rainbow trout by electrofishing is of concern in Alaska (Holmes et al. 1990). Use of brand names in this thesis does not imply endorsement by the Alaska Cooperative Fish and Wildlife Research Unit or its sponsors.

Injury Experiment

Homogeneous electrical field.--An initial injury experiment was conducted using a homogeneous electrical field during June 26-29, and July 18-19, 1990 and July 30, 1991. The field was created in a plastic tank 91 x 61 and 46 cm deep, with 1.6 mm thick aluminum sheet electrodes 61 x 46 cm at each end. The electrodes were wired to a Coffelt model VVP-3E or VVP-15 (variable voltage pulsator) to test the following waveforms: alternating current (AC); smooth direct current (DC); and Complex Pulse System (CPS^{TM}) developed by Coffelt Manufacturing Company, Flagstaff, Arizona. Three types of pulsed direct current were also tested: PDC 60/50 (60 Hz, 50% duty cycle); PDC 30/50 (30 Hz, 50% duty cycle); and PDC 30/75 (30 Hz, 75% duty cycle). (Duty cycle is the percentage of time a pulse is on during one cycle of a PDC waveform.) Fish were exposed to a threshold level (low voltage (100V on VVP) at which the fish was first stunned) and a maximum level (highest VVP voltage (400V on VVP)). Some fish were also shocked with DC at a level which induced galvanotaxis (forced swimming toward the anode or positive electrode).

Sample size was 12 fish per treatment (waveform and voltage level)(13 treatments x 12 fish=156 fish). Also, 56 control fish were treated and handled in the same manner as shocked fish, but were not shocked. Conductivity and temperature of the water were 100-121 µS/cm and 9-13°C.

Fish were randomly assigned to a treatment or control group. Each fish was placed individually into the test tank and exposed to the waveform for 5 seconds. The fish was allowed to recover and then killed with an overdose of tricaine methanesulfonate (MS-222). Fish were marked with numbered dart tags. The tag number, recovery time(s), fork length (mm), and weight (g) of the fish were recorded. The fish were frozen for later X-ray and necropsy examination. X-rays were taken from a lateral view and examined and rated for spinal injury. The fish were then partially thawed, filleted on both sides, examined and rated for internal hemorrhage.

Criteria for spinal injury ratings were: 0- no spinal damage apparent; 1- compression of the vertebrae only; 2- misalignment of vertebrae, including compression, if any; and 3- fracture of one or more vertebrae or complete separation of two or more vertebrae. Internal hemorrhage rating criteria were: 0- no hemorrhage apparent; 1- mild hemorrhage (one or more wounds in the muscle, separate from the spine); 2- moderate hemorrhage (one or more small wounds on the spine, each less than the width of two vertebrae); and 3- severe hemorrhage (one or more large wounds on the spine, each equal to or greater than the width of two vertebrae). Through X-ray examination of the control fish it was determined that natural spinal abnormalities or old spinal injuries could be differentiated from new spinal injury (Sharber and Carothers 1988). Natural spinal abnormalities had dense or fused vertebrae and often appeared calcified (cartilage buildup around the injury and more opaque on the X-ray). Old spinal injuries were calcified.

Heterogeneous electrical field.--The second injury experiment simulated conditions found in a normal electrofishing situation with a heterogeneous electrical

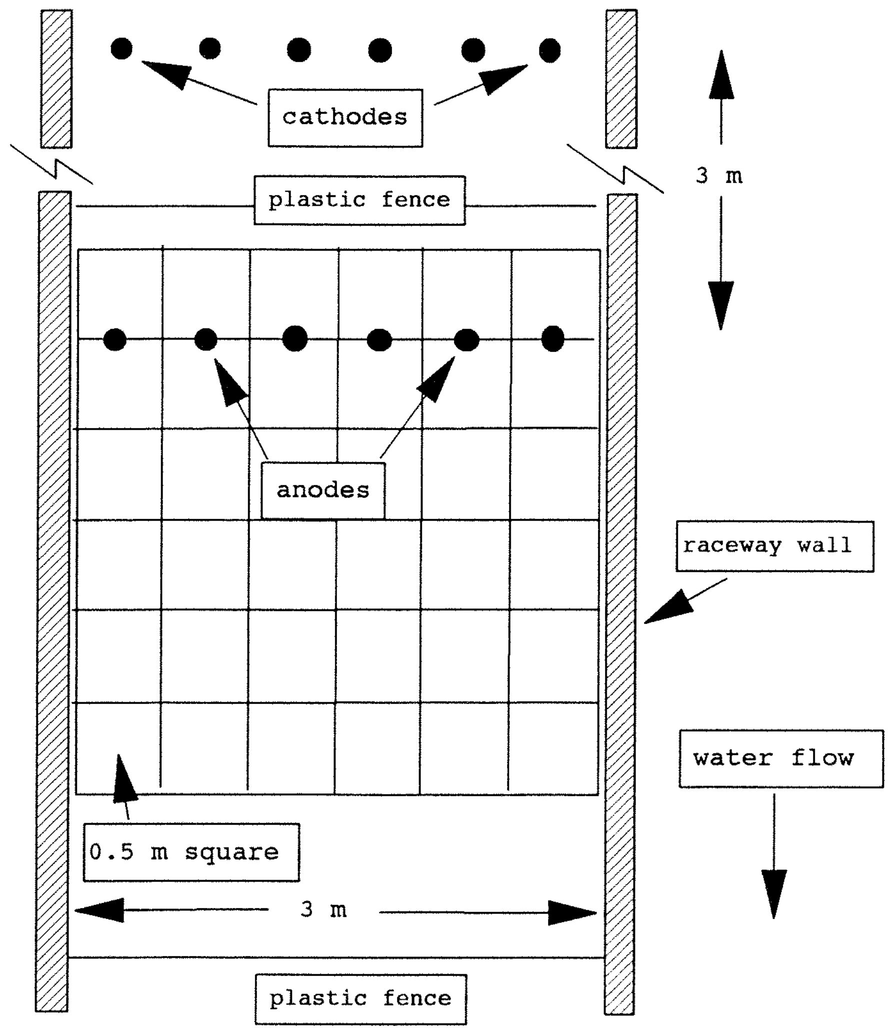

Figure 1. Overhead view of the heterogeneous field experiment.

field. This experiment was conducted on August 1, 1991 in a concrete raceway 3.08 m wide with slowly-flowing water 0.46 m deep at the Fort Richardson Hatchery, Anchorage, Alaska (Figure 1). Water conductivity and temperature were 103 µS/cm and 11°C. A 3 x 3 m grid (0.5 x 0.5 m squares) was placed on the bottom of the raceway and two electrode systems were placed on one end of the grid. The grid was made of white PVC pipe (2 cm diameter). Its purpose was to provide intersection points at which the electrical field could be mapped, and the voltage gradient (V/cm) to which the fish was exposed could be determined by its location on the grid. The anodes were placed 0.5 m in from the edge of the grid and simulated the shocking boom of a electrofishing boat (6 metal cylinders, each 2 cm in diameter, and spaced at 0.5 m intervals across the raceway). The cathode (same design as the anode) was placed 2.5 m from the edge of the grid, behind the anode. A plastic fence was placed between the two electrode arrays; another was placed 1.0 m from the opposite edge of the grid to prevent fish from escaping to other parts of the raceway.

The electrical fields were mapped (29 cm below the surface) at the intersection points of the grid and at the electrodes for each of the selected waveforms: DC, CPS™, and PDC 20/25, PDC 20/75, PDC 60/50, and PDC 30/50. Rainbow trout (>300 mm) were selected randomly and placed individually in the raceway at the end of the grid opposite the electrodes. Each fish was exposed to one of the six randomly selected waveforms and forced (scared by arm waving or chased by a net) to swim into the electrical field where it was shocked for 5 seconds. The fish were exposed to 200V, 4.5A (VVP setting), except for CPS™, with which the fish were exposed to 400V, 10A. This higher setting for CPS™ was required to stun the fish with that waveform. The entire process was videotaped with a camera (18 feet above the raceway, centered on the grid) for later analysis to determine the fish's location on the grid and it's recovery time. Fish were then anesthetized (MS-222), tagged, X-rayed, and measured (length and weight), and placed into another raceway to be held for the long-term survival portion of the experiment. Sample size was 12 fish per treatment (6 treatments x 12 fish=72 fish). The fish were held as a group for 182 days and fed standard hatchery pellets daily. Dead fish were removed daily and tag number and date of death recorded. After 182 days the fish were anesthetized and the tag number, length and weight recorded.

Analysis of internal injury.--To test for correlation between spinal injury and internal hemorrhage in the homogeneous field experiment, the log-likelihood ratio (*G* statistic) was used (Zar 1984, BMDP 1990). This test provided the means to determine differences in: spinal injury among treatments in both experiments; internal hemorrhage among treatments in the homogeneous field experiment; and mortality among treatments in the heterogeneous field experiment. A two factor ANOVA (*F* statistic) was used to test for difference in length of injured (spinal injury) and uninjured fish or among treatments (SAS 1989). The Kruskal-Wallis test (*H* statistic) was used to determine difference in mean length among treatments (Zar 1984, BMDP 1990). All tests were conducted at the 95% level of confidence.

<u>Long-term Mortality Experiment</u>

The long-term mortality experiment was initiated at the Fort Richardson Hatchery on July 9-10, 1991. The purpose of this experiment was to examine mortality rates of treatment fish (shocked-uninjured and shocked-injured) and control fish. Sample size was 102 shocked and 50 control fish, each randomly designated. Treatment fish were individually placed into the homogeneous field tank and exposed to 250V (mean V/cm=2.30) of PDC 60/50 for 5 seconds. The fish was allowed to recover and recovery time recorded. Both shocked and control fish were then anesthetized (MS-222), X-rayed (lateral view), measured (length and weight), placed into a raceway and held for 203 days with the 72 heterogeneous field experiment fish. The fish were fed daily and dead fish were removed, tag number and date of death recorded.

Analysis of mortality.--To test for difference in mortality between shocked and control fish, the log-likelihood-ratio (*G* statistic) was used (Zar 1984, BMDP 1990). This test was also used in a pairwise comparison between shocked-uninjured, shocked-injured, and control fish for difference in mortality. The Mann-Whitney test (*U* statistic) was used to determine difference in mean length between shocked and control, and shocked-uninjured and shocked-injured fish (Zar 1984, BMDP 1990). The Kolmogorov-Smirnov goodness of fit for continuous data (*D* statistic) was used to test difference in mortality over time between treatments (Zar 1984). The Mann-Whitney test (*U* statistic) was used to examine effects of shocking on growth by testing the mean difference in length and weight of surviving shocked fish against control fish . All tests were conducted at the 95% level of confidence.

Field Trial Experiment

This experiment was conducted on Lake Creek, Alaska on the Susitna River drainage during September 24-26, 1991. Lake Creek was selected as the experiment site because (1) it contained a population of large (>300 mm) rainbow trout with no previous exposure to electrofishing and (2) it offered an alternative to the Kenai River where electrofishing injury of large rainbow trout was a public issue.

Three waveforms (DC, CPS™ and PDC 25/75) were selected on the basis of low injury rates from the heterogeneous field injury experiment. Fifteen percent spinal injury was the arbitrary maximum level of injury considered acceptable. An electrofishing boat was used with a Coffelt VVP-15 and a Kawasaki 4000-watt generator. Water conductivity and temperature were 30 µS/cm and 7°C. Two netters were used and only rainbow trout were captured. Two trials were conducted, one each day. The first trial compared the DC and CPS™ waveforms; these were used randomly in 16 5-minute replicates. The second trial compared the DC and PDC 25/75 waveforms; these were used randomly in 24 5-minute replicates. Due to low water and fish abundance, repeated passes were conducted for the replicates. In both trials, the number of fish captured and the number of fish that were stunned but not captured were recorded during each 5 minute period. After the fish were captured they were tagged, measured (length and weight), and placed into holding pens. The fish were then anesthetized (MS-222) and X-rayed (lateral view), and placed back into the holding pens and held for 5 days for evaluation of short-term mortality. The holding pens were examined daily for mortalities and after 5 days the surviving fish were released.

Analysis of injury and capture rates --The log-likelihood ratio (*G* statistic) was used to determine differences in: spinal injury between treatments in each trial; and proportion of injured fish to captured fish by sampling day (Zar 1984, BMDP 1990). This second test was run to determine if the proportion of injured fish increased as a result of capturing fish injured in a previous pass, thereby biasing the test. The Mann-Whitney test (*U* statistic) was used to test for difference in mean length and mean capture and escape rates between treatments. All tests were conducted at the 95% level of confidence.

Results

Injury Experiment

Homogeneous field experiment.--There was no significant difference in injury rates between low and high exposures (DC:G=0.689, 1 d.f., P=0.4064; CPS^{TM}:G=0.254, 1 d.f., P=0.6143; AC:G=0.756, 1 d.f., P=0.3846; PDC 60/50:G=0.670, 1 d.f., P=0.4131; PDC 30/75:G=0.001, 1 d.f., P=1.000; PDC 30/50:G=0.168, 1 d.f., P=0.6819); therefore, the data were combined and examined as one group for analysis (Table 7, Appendix). This allowed comparison to the heterogeneous field experiment results. Incidence of spinal injury was highest with AC (67%), and lowest with CPS^{TM} (21%) (Figure 2). The control fish had a 4% spinal injury rate, which may have been caused by handling. There was a significant difference in spinal injury rates among all groups (G=49.055, 6 d.f, $P<0.0001$). Differences among treatments persisted, even when the control group was removed from the analysis (G=14.576, 5 d.f., P=0.0123).

Internal hemorrhage injury rates were highest in the PDC 30/75 and 30/50 waveforms at 46%; DC gave the lowest hemorrhage rate at 28% (Table 1). The control group had 2% internal hemorrhage injury rate. There was a significant difference in internal hemorrhage rate among groups (G=41.798, 6 d.f., $P<0.0001$), but when the control group was

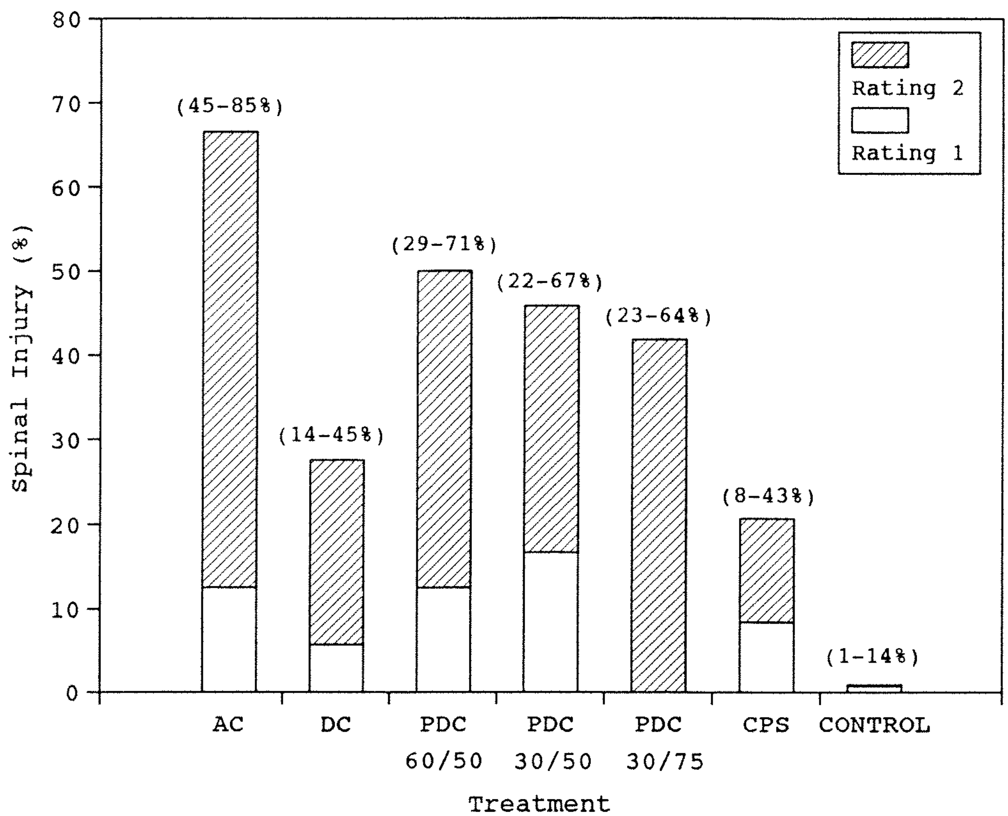

Figure 2. Spinal injury by rating from various waveforms in a homogeneous electrical field. Percent confidence limits for total injury rates are in parentheses.

Table 1. Voltage gradient, fish length, and rates of injury (95% confidence limits in parentheses) for waveforms used in the homogeneous experiment conducted June 26-29, July 19, 1990 and July 30, 1991 at the Fort Richardson Hatchery, Anchorage, Alaska.

Waveform	n	Voltage gradient (V/cm)		Fish length (mm)		Spinal injury (%)	Internal hemorrhage (%)
		mean	SD	mean	SD		
Low Voltage							
DC	18	0.51	0.16	455	31	33 (13-59)	28 (10-54)
CPS	12	0.12	0.01	412	20	17 (3-49)	33 (10-65)
AC	12	0.21	0.03	464	50	58 (28-85)	25 (6-57)
PDC 60/50	12	0.36	0.10	478	55	58 (28-85)	50 (22-79)
PDC 30/75	12	0.96	0.35	401	27	42 (16-72)	58 (28-85)
PDC 30/50	12	0.70	0.52	410	49	58 (28-85)	42 (16-72)
High Voltage							
DC	18	0.94	0.21	469	33	22 (7-48)	28 (10-54)
CPS	12	0.42	0.08	386	29	25 (6-57)	50 (22-79)
AC	12	3.43	0.51	482	62	75 (43-94)	58 (28-85)
PDC 60/50	12	2.39	0.51	463	55	42 (16-72)	33 (10-65)
PDC 30/75	12	3.45	0.38	399	25	42 (16-72)	33 (10-65)
PDC 30/50	12	2.41	0.35	387	125	33 (10-65)	50 (22-79)
CONTROL	56	N/A	N/A	444	60	4 (1-14)	2 (0-11)

removed, there was no difference among treatments (*G*=3.190, 5 d.f., P=.6708). A correlation between spinal injury and internal hemorrhage was found in two treatments, low voltage AC (*G*=3.935, 1 d.f., P=0.0473) and high voltage PDC 30/50 (*G*=7.638, 1 d.f., P=0.0057). The remaining treatments had low correlation between spinal injury and internal hemorrhage (*G*<2.805, 1 d.f., P>0.0940).

No rating 3 spinal injuries were found in the homogeneous field experiment (Figure 2). Rating 2 spinal injuries were most predominant, PDC 30/75 caused only rating 2 spinal injuries. There was a significant difference in spinal injury ratings among treatments (*G*=62.067, 12 d.f., P<0.0001).

There was a significant difference in mean lengths of fish among treatments (*H*=76.04, 6 d.f., P<0.0001) and between injured and uninjured fish within treatments (ANOVA *F*=3.64, 6, 198 d.f., P=0.0019); but with the control group removed there was no significant difference between injured and uninjured fish within treatments (*F*=1.06, 5, 144 d.f., P=0.3872) (Table 1, Figure 3). The two injured fish in the control group were exceptionally large fish (>500 mm) which resulted in the difference in mean lengths between injured and uninjured in the control group; this is the reason for

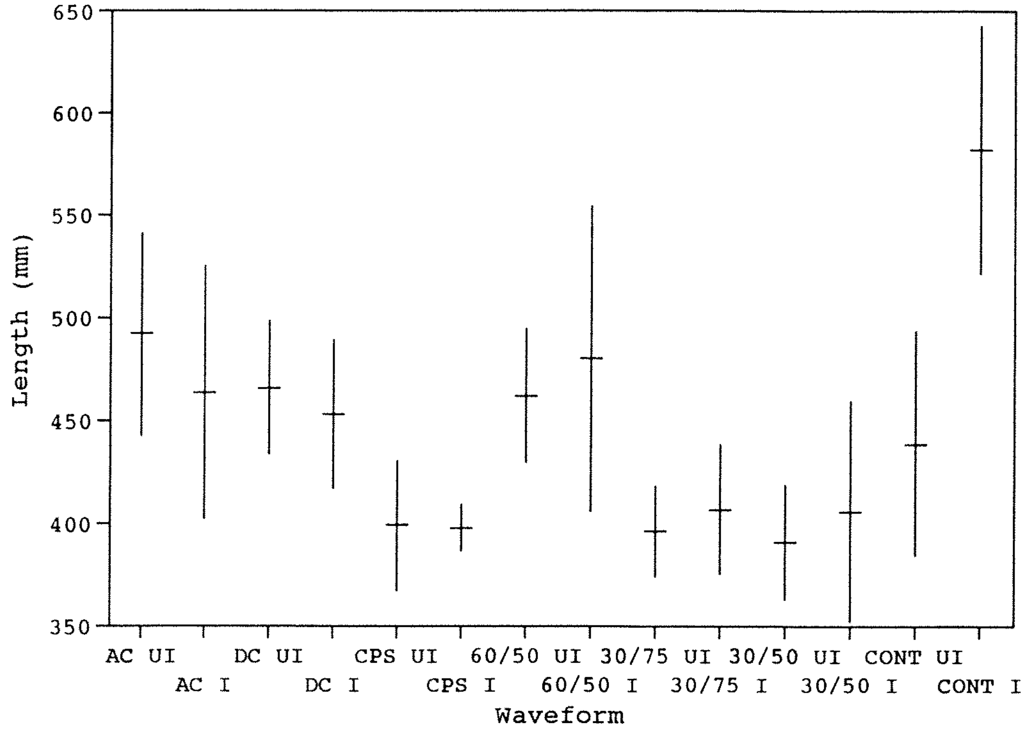

Figure 3. Mean length (+/- 1 SD) by waveform and injured (I) and uninjured (UI) fish in the homogeneous field experiment.

no difference in mean lengths within treatments when the control group was removed.

Heterogeneous field experiment.--The highest incidence of spinal injury was found in PDC 60/50 at 67%; CPS^{TM} had the lowest injury rate at 8% (Table 2 and Table 8, Appendix). There were also significant differences in spinal injury rates (G=14.935, 5 d.f., P=0.0106) and in spinal injury ratings (G=18.739, 10 d.f., P=0.0437) among waveforms. The PDC 30/50, PDC 20/75, and CPS^{TM} waveforms caused only rating 2 spinal injuries. PDC 60/50 and PDC 20/25 caused mostly rating 2 injuries, and DC gave equal percentage of rating 1 and rating 2 spinal injuries (Figure 4). There were no rating 3 spinal injuries in the heterogeneous field experiment.

There was no significant difference in mean lengths among treatments (H=5.19, 5 d.f., P=0.3936); and between injured and uninjured fish within waveforms (ANOVA F=0.94, 5, 60 d.f., P=0.4628) (Table 2, Figure 5). In a comparison of similar waveforms between the two injury experiments, there was no significant difference in injury rates between homogeneous and heterogeneous fields (DC:G=0.630, 1 d.f., P=0.4273, CPS^{TM}:G=0.993, 1 d.f., P=0.3191, PDC 60/50:G=0.914, 1 d.f., P=0.3391, PDC 30/50:G=1.415, 1 d.f., P=0.2342) (Figure 6).

Table 2. Mean fish length, maximum voltage gradient, percent spinal injury and mortality (95% confidence limits in parentheses) for waveforms used in the heterogeneous field experiment conducted August 1, 1991 at the Fort Richardson Hatchery, Anchorage, Alaska.

		Fish length (mm)		Voltage gradient (V/cm)		Spinal injury (%)	Mortality (%)
Waveform	n	mean	SD	maximum	SD		
PDC 60/5	12	389	39	2.60	0.70	67 (35-90)	8 (1-38)
PDC 30/5	12	398	28	4.36	1.48	33 (10-65)	33 (10-65)
PDC 20/7	12	421	59	5.82	1.98	25 (6-58)	17 (3-48)
PDC 20/2	12	405	41	1.53	0.70	58 (28-85)	25 (6-58)
DC	12	400	30	9.01	2.51	17 (3-48)	0 (0-27)
CPS	12	382	44	0.44	0.12	8 (1-38)	8 (1-38)

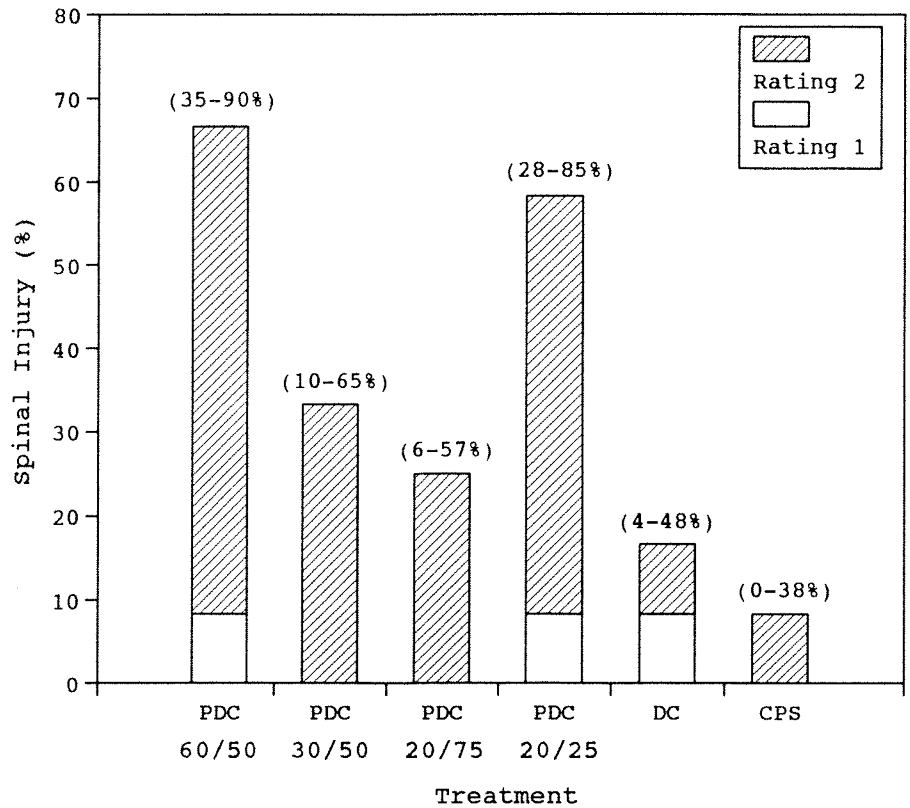

Figure 4. Spinal injury by rating from various waveforms in a heterogeneous electrical field. Percent confidence limits for total injury rates are in parentheses.

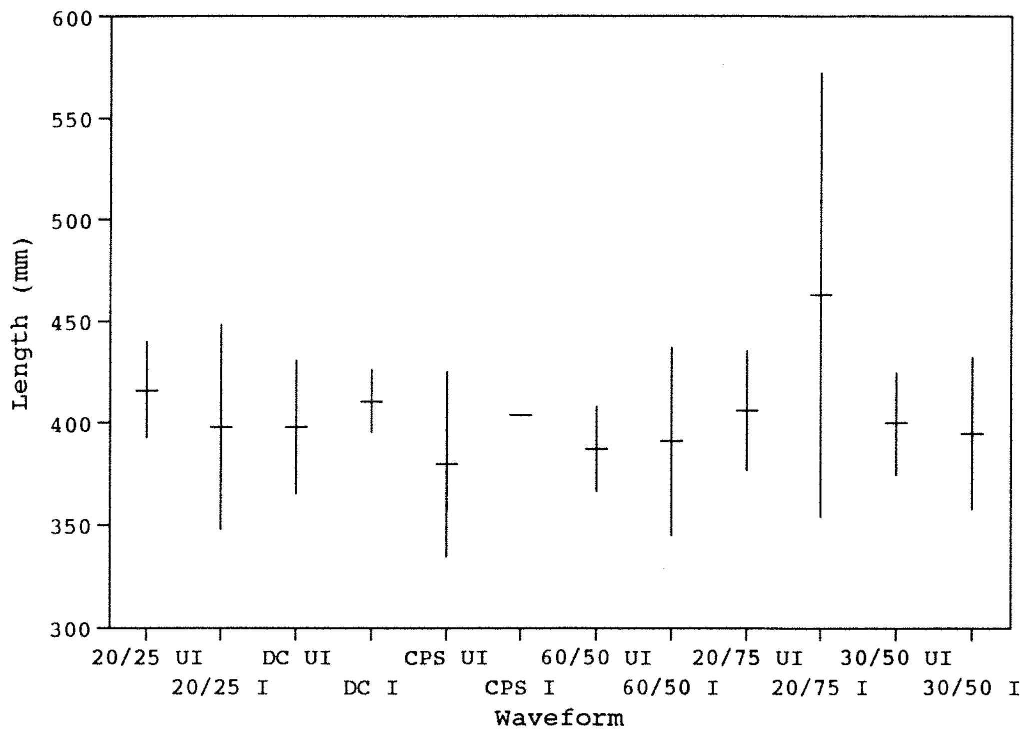

Figure 5. Mean length (+/- 1 SD) by waveform and injured (I) and uninjured (UI) fish in the heterogeneous field experiment.

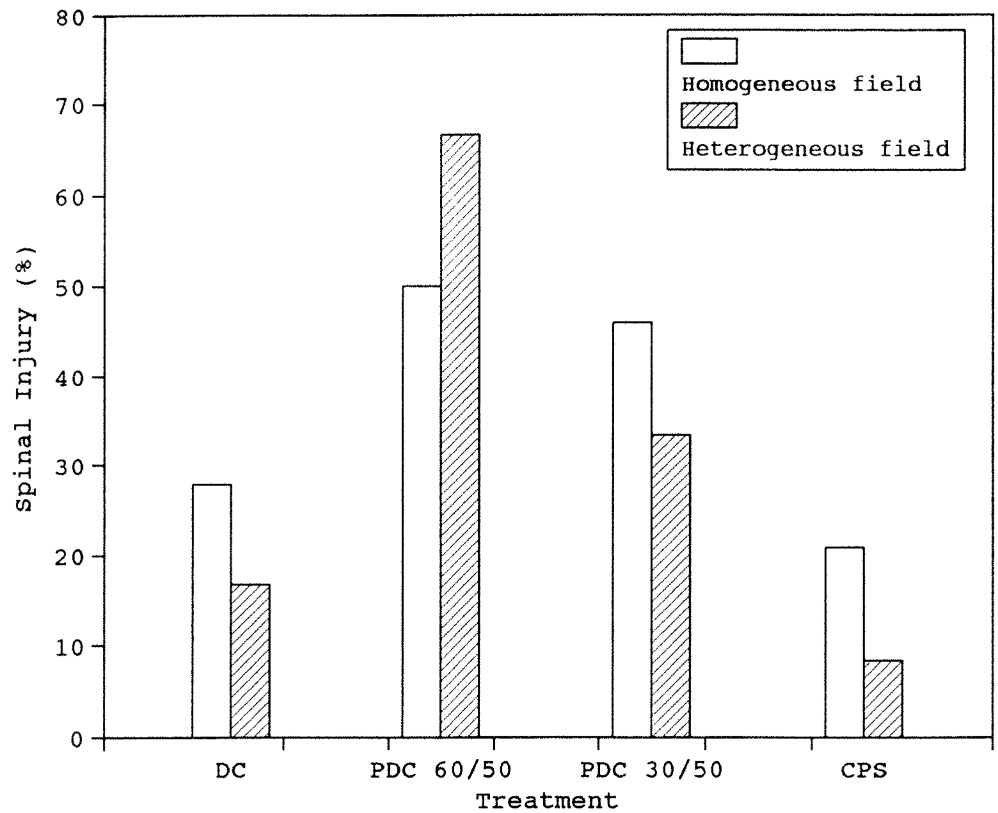

Figure 6. Comparison of spinal injury rates of similar treatments in homogeneous and heterogeneous electrical fields.

Long-term Mortality Experiment

There was a 10% incidence of mortality in control fish and a 35% incidence of mortality in shocked fish after 203 days, a significant difference (G=6.738, 1 d.f., P=0.0094) (Figure 7 and Table 9, Appendix). There was 52% mortality in shocked-injured fish and 29% mortality in shocked-uninjured fish, not a significant difference (*G*=0.749, 1 d.f., 0.3866) (Table 3, Figure 8). There was a significant difference in mortality between control and shocked-injured fish (*G*=6.410, 1 d.f., P=0.0113), and control and shocked-uninjured fish (*G*=4.814, 1 d.f., P=0.0282).

Mean lengths of control and shocked fish were not significantly different (*U*=2211, P=0.1830) (Table 3). There was also no difference in mean length of control, shocked-uninjured, and shocked-injured (*H*=4.68, 2 d.f., P=0.0965).

Twenty-eight spinal injuries were detected in the 152 fish sample, 27 injuries in the shocked fish (7-rating 1, 19-rating 2, 1-rating 3) and one rating 1 injury in the control fish (Table 4). There was no difference in mortality among uninjured, rating 1, rating 2, and rating 3 spinal injury fish (*G*=3.895, 3 d.f., P=0.2730).

Eighty-three percent of the deaths occurred within the first 30 days after shocking. There was a significant

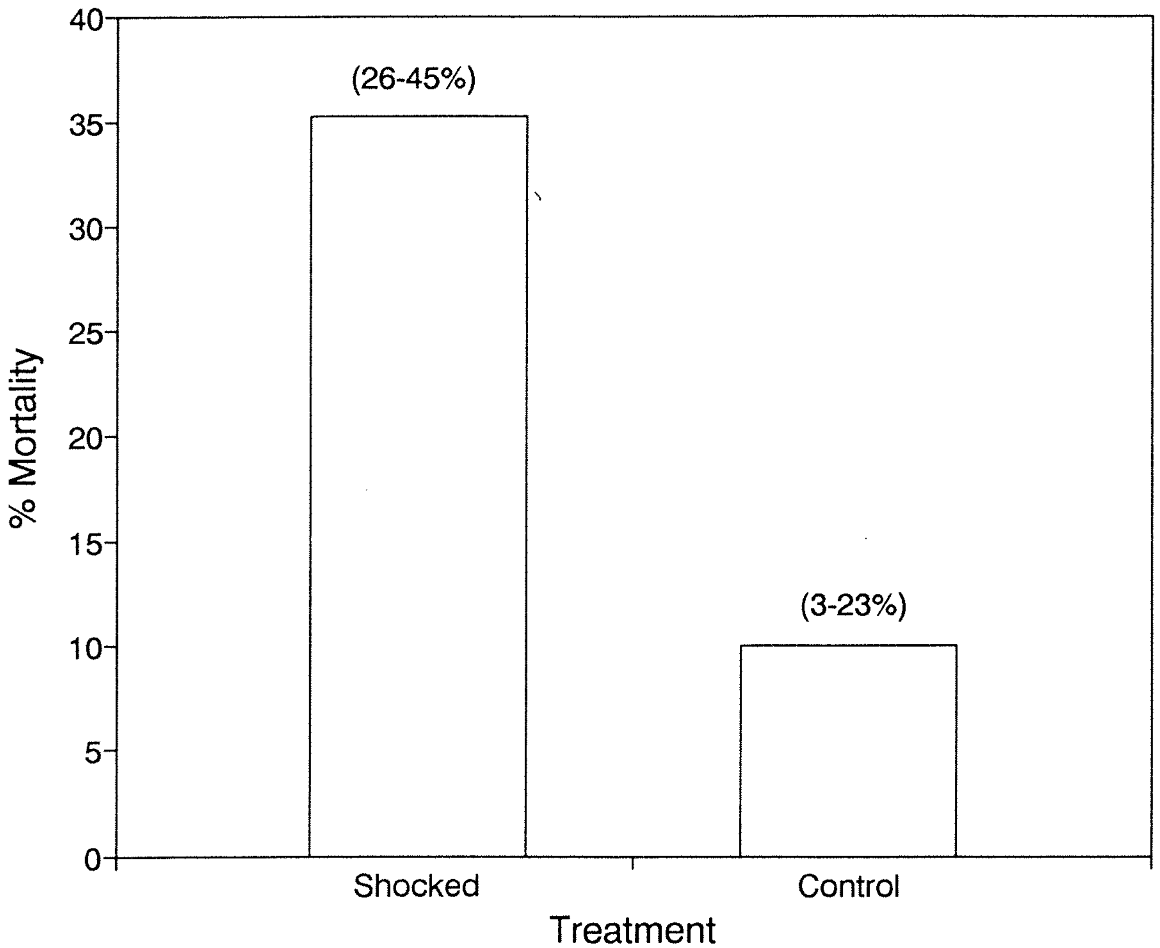

Figure 7. Mortality caused by PDC 60/50 in a homogeneous electrical field. Percent confidence limits are in parentheses.

Table 3. Voltage gradient, fish length, percent mortality (95% confidence limits in parentheses) for the long-term mortality experiment initiated July 9-10, 1991 at the Fort Richardson Hatchery, Anchorage, Alaska.

Treatment	n	Voltage gradient (V/cm)		Fish length (mm)		Number dead	Mortality rate (%)
		mean	SD	mean	SD		
Shocked/ Injured	27	2.29	0.14	407	45	14	52 (33-72)
Shocked/ Uninjured	75	2.31	0.16	391	37	22	29 (18-41)
Control	50	N/A	N/A	385	39	5	10 (3-23)

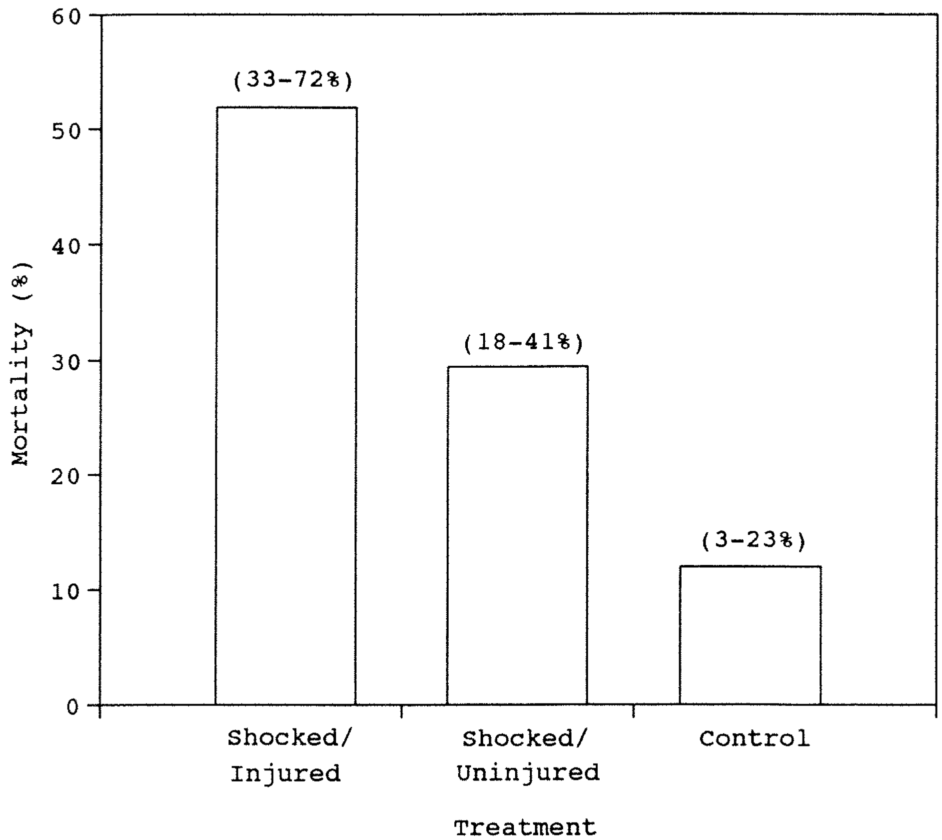

Figure 8. Mortality caused by PDC 60/50 in a homogeneous electrical field by shocked-injured, shocked-uninjured, and control groups. Percent confidence limits are in parentheses.

Table 4. Number of fish with various ratings of spinal injury by treatment in the long-term mortality experiment.

		Injury rating			
Treatment	n	0	1	2	3
Shocked	102	75	7	19	1
Control	50	49	1	0	0

difference in mortality over time between shocked and control fish, and between shocked-injured, and shocked-uninjured and control fish (D=0.8333, $P<0.001$) (Figure 9).

After 182 days, there was no significant difference in mortality among waveforms in the heterogeneous field experiment (G=8.206, 5 d.f., P=0.1453) even though percent mortality ranged from 0% (DC) to 33% (PDC 30/50): this was most likely due to small sample size (Table 2).

High tag loss occurred among fish being held in the raceway for the long-term mortality experiment; 27 (38%) fish from the heterogeneous field experiment, and 56 (37%) fish from the homogeneous field experiment could not be identified at the end of the experiment. This tag loss reduced the sample sizes for the growth experiment, because individual fish could not be identified for final measurement of length and weight. Tag loss did not affect the results of the long-term mortality experiment.

Surviving fish from the homogeneous field experiment showed no significant differences in mean lengths (H=0.48, 2 d.f., P=0.7847) or weights (H=1.00, 2 d.f., P=0.6057) among control, shocked-uninjured, and shocked-injured groups (Table 5). Also, no significant difference occurred in mean length (U=278.0, P=0.7793) or weight (U=286.5, P=0.9077) of

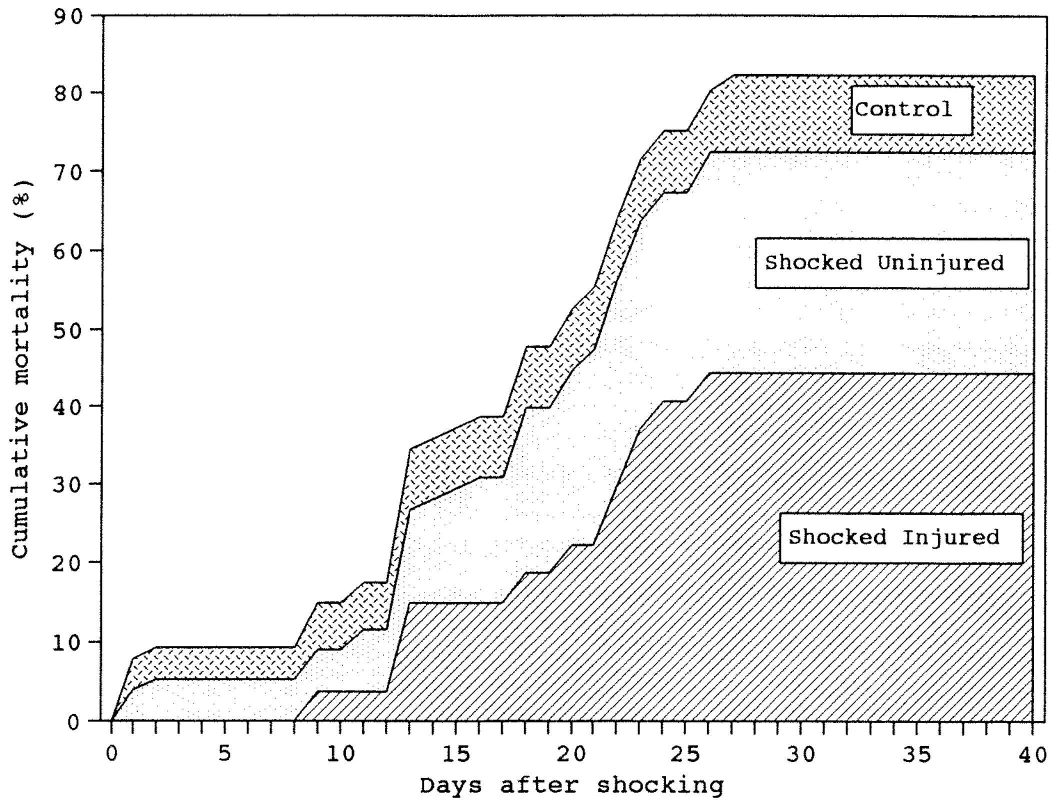

Figure 9. Cumulative mortality caused by PDC 60/50 over 40 days.

Table 5. Percent mortality, growth sample size, and mean difference in length and weight by group for the homogeneous and heterogeneous experiments.

Treatment	Mortality (%)	Growth sample size	Mean difference in length (mm)	Mean difference in weight (g)
Homogeneous field				
Shocked-injured	52	4	29	320
Shocked-uninjured	29	35	42	381
Control	10	15	37	355
Heterogeneous field				
PDC 60/50	8	4	26	190
PDC 30/50	25	5	40	430
PDC 20/75	17	5	23	280
PDC 20/25	25	6	20	260
DC	0	10	30	291
CPS	8	5	26	200

surviving fish between shocked and control groups. Surviving fish from the heterogeneous field experiment showed no differences in mean lengths (*H*=4.58, 5 d.f., P=0.4698) or weights (*H*=6.26, 5 d.f., P=0.2818) among treatments (waveforms). On the average, all groups exhibited increases in length (7%) and weight (47%) during the 203-day experiment.

Field Trial Experiment

Because sample replicates were taken over the same stretch of water, there was concern about bias resulting from the capture of fish with one waveform after being injured by another. Therefore, the proportion of injured to captured fish was compared by sampling day (Figure 10). There was a significant difference in percent injured fish among the three sampling days (*G*=5.569, 2 d.f., P=0.0617); also between day two and day three (*G*=5.427, 1 d.f., P=0.0198); but none between day one and two (*G*=1.900, 1 d.f., P=0.1681) or day one and three (*G*=1.672, 1 d.f., P=0.1959). Nineteen replicates were conducted on day two, while only 5 were conducted on day three. DC gave 0 injuries on day two and 4 (57%) injuries on day three, a significant difference (*G*=11.301, 1 d.f., P=0.0008). PDC 25/75 gave 4 (57%) injuries on day two and 2 (67%) injuries

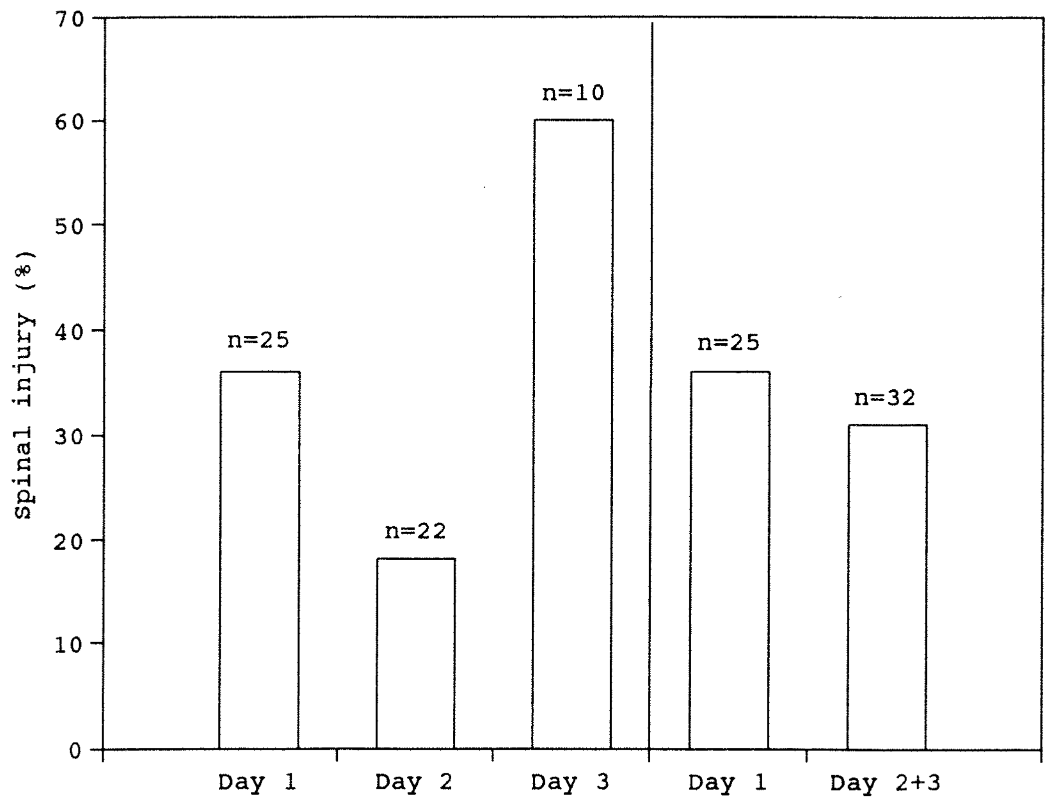

Figure 10. Spinal injury by sampling day for field trials conducted at Lake Creek, Alaska.

on day three, not a significant difference (G=0.080, 1 d.f., P=0.7767).

From the test results it appeared that previously injured fish may have been captured on day three. When day two and three injury results were combined, there was no significant difference in percent injury between the two field trials (G=0.142, 1 d.f., P=0.7061) (Figure 10). Conclusions from this are not clear, but this difference between days may be caused by small sample size on the third day. To determine if the third day sample biased the results of trial two, the tests were run without day three data. The results were similar between day two only, and day two and three combined: a significant difference in spinal injury between DC and PDC 25/75 (G=11.301, 1 d.f., P=0.0008); no difference in mean length of captured fish (U=201.50, P=0.6281); no difference in capture rates (U=51.00, P=0.6142) or escape rates (U=50.50, P=0.6422). Despite the similarity of the overall results with day 3 included, it appears that injury rates for DC on the third day may be biased. The data used for the injury rate analysis of trial two was from day 2 only. Mean length, capture and escape rates analysis used both day two and three data.

The incidence of spinal injury in the first field trial was 47% for DC and 13% for CPS^{TM} (Table 6, Figure 11 and Table 10, Appendix). Number of fish X-rayed for spinal injury for DC was 17; one fish escaped in the handling process. There was no difference in spinal injury rates between DC and CPS^{TM} (G=3.134, 1 d.f., P=0.0767). Incidence of spinal injury in the second field trial was 0% for DC and 57% for PDC 25/75. Number of fish used for spinal injury results were 15 for DC and 7 for PDC 25/75. The other fish captured with these waveforms had X-rays that were unreadable. There was a significant difference in spinal injury rates between DC and PDC 25/75 (G=11.301, 1 d.f., P=0.0008).

The mean length of fish captured in the first field trial was 323 for DC and 395 mm for CPS^{TM} (Table 6), a significant difference (U=17.50, P=0.0025). The mean length of fish captured in the second field trial was 338 for DC and 355 mm for PDC 25/75, not a significant difference (U=279.0, P=0.3493).

There was no difference in capture rates between DC and CPS^{TM} (U=16.0, P=0.1366) or DC and PDC 25/75 (U=81.5, P=0.5541) (Figure 12). The same was true for escape rates between DC and CPS^{TM} (U=14.0, P=0.3252) or DC and PDC 25/75 (U=70.5, P=0.9525).

Table 6. Number of fish captured, mean number of fish captured, fish length, percent injury and mortality (95% confidence limits in parentheses) for field trial experiments conducted September 24-26, 1991 at Lake Creek, Alaska.

Waveform	Replicates	Fish captured			Fish length (mm)		Spinal injury (%)	Mortality (%)
		n	mean	SD	mean	SD		
DC-1	8	18	2.1	1.19	323	47	47 (24-72)	11
CPS	10	8	0.8	0.51	395	46	13 (1-54)	0
DC-2	13	33	2.5	2.24	338	69	0 (0-22)	3
PDC 25/75	11	20	1.8	1.19	355	70	57 (20-88)	15

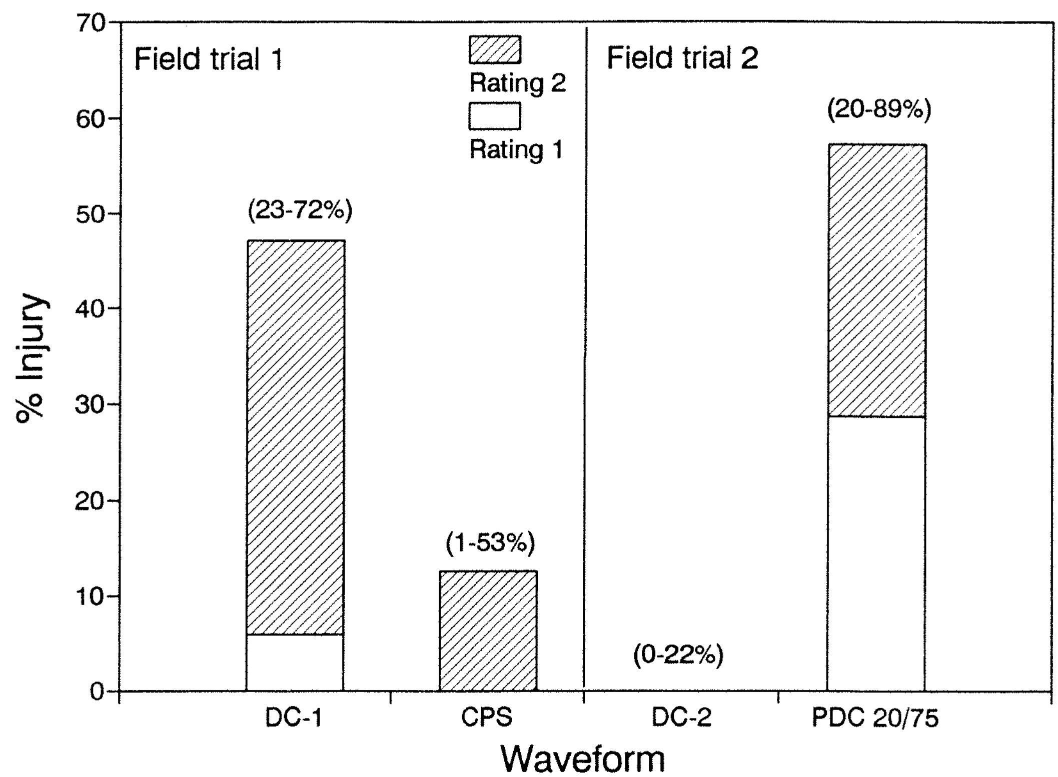

Figure 11. Percent spinal injury by rating from the two field trial experiments. Percent confidence limits for total injury rates are in parentheses.

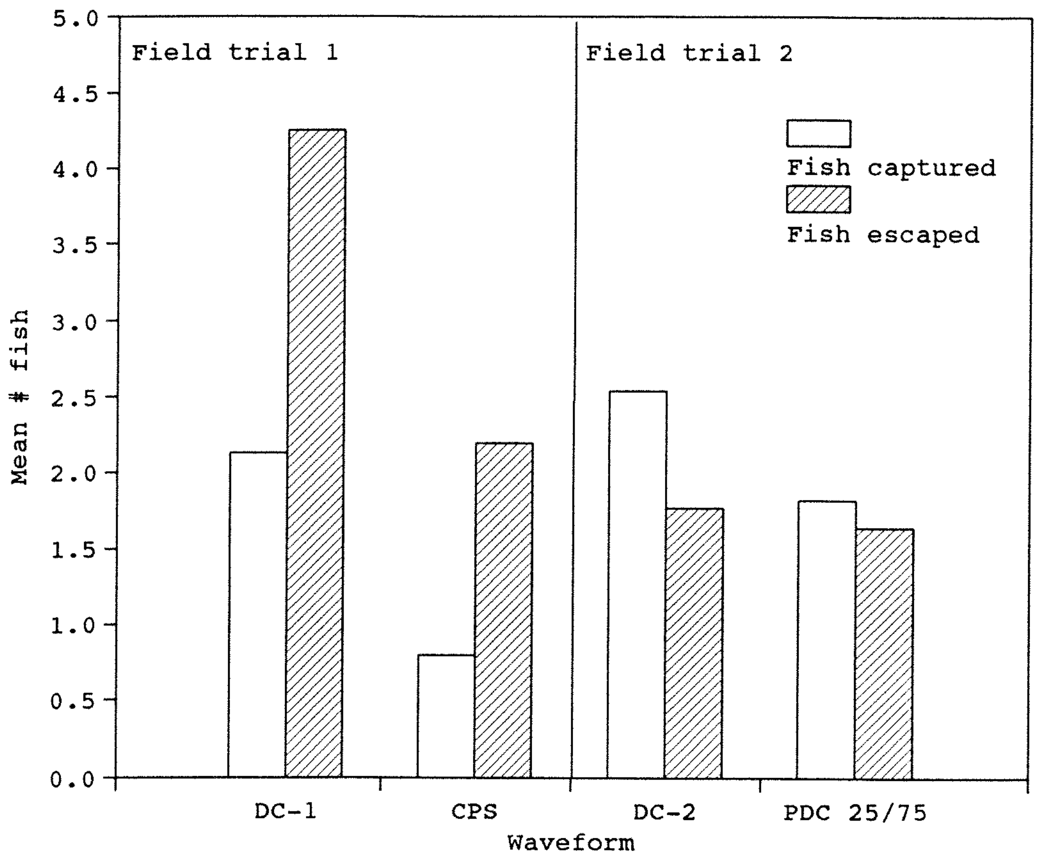

Figure 12. Capture and escape rates by waveform and field trial per five minute electrofishing effort.

Mortality after 5 days was greatest among fish caught with PDC 25/75 (15%) (Table 6). DC gave 11% mortality in trial 1 and 3% mortality in trial 2. CPS™ gave no mortalities after 5 days.

Discussion

Spinal injury rates due to exposure to both the homogeneous and heterogeneous electrical fields were similar. PDC generally caused high rates of spinal injury, 25-75%, while DC and CPS™ caused relatively low injury rates, 8-33% (Tables 1 and 2). The results for PDC were similar to the studies of Sharber and Carothers (1988) and Holmes et al. (1990) where spinal injury rates ranged from 41-67%. The PDC waveforms with a low frequency and high duty cycle tended to have lower, but unacceptable, rates of spinal injury.

Internal hemorrhage rates for all waveforms tested in the homogeneous field experiment were not significantly different and there was little or no correlation between internal hemorrhage and spinal injury. It would appear that spinal injury and internal hemorrhage are not directly related and could occur independently of each other, though a larger sample size for each waveform might be more conclusive.

Despite a significant difference in mean lengths among treatments in the homogeneous field experiment, there was no difference in mean lengths between injured and uninjured fish within treatments. The same was true for the heterogeneous field experiment and between injured and uninjured fish within treatments. There was also no difference in mean lengths among shocked-injured, shocked-uninjured, and control fish in the long-term mortality experiment. Although larger fish are reported to be more sensitive to electrical fields (Sullivan 1956), no such length bias occurred in my experiments.

No significant differences occurred in mortality rates between waveforms in the heterogeneous field experiment, though three waveforms gave mortalities above 10%, which probably would not be acceptable for most mark-recapture studies. PDC 60/50 caused 34% mortality in the long-term mortality experiment, which used a homogeneous field and a sample size over 8 times greater than that of the heterogeneous field experiment in which the same waveform caused 8% mortality. Though there was no significant difference in injury rates between homogeneous and heterogeneous electrical fields, there was a trend for lower injury from the heterogeneous field. This could be explained by the fact that a fish has no chance of escaping to a lower voltage gradient in a homogeneous field because the field is uniform. In a heterogeneous field the fish could escape or it's momentum could move it to a lower voltage gradient. Holmes et. al. (1990) had reported 14% short-term mortality in large rainbow trout captured with

PDC 60/50, which is similar to the results of the heterogeneous field experiment.

Another concern in the mortality results is how these results apply to wild rainbow trout. An injured trout in a hatchery is more likely to survive than a wild trout which must face its environment, avoid predators, and capture prey. One might expect that mortality rates among shocked fish in a wild population would be higher. Mesa and Schreck (1989) reported wild cutthroat trout appeared to be more severely affected (decreased rates of feeding and aggression) after capture by electrofishing and took longer to regain normal behavior than hatchery fish. A controlled, long-term electrofishing study of mortality in wild rainbow trout would be difficult; holding pens would cause additional stress that could increase mortality. An ideal study situation would occur in a small lake with an adequate food supply, that could be monitored for mortalities and enable all fish to be collected or accounted for at the end of the experiment.

In all control and field trial experiments at least half of the spinal injuries were rating 2 for each waveform. There was no difference in mortality among ratings, suggesting that the severity of the spinal injury does not affect survival of rainbow trout. The rating system developed for this project was arbitrarily set to identify different injuries, and may not accurately reflect severity of injury. There was only one rating 3 injury in the long-term mortality experiment and that fish was still alive after 203 days. The lack of rating 3 injuries in both the hatchery and field experiments may indicate that severe spinal injuries in rainbow trout captured with these waveforms and under these water conditions are unlikely.

Eighty-three percent of the mortalities occurred within 30 days after shocking; 78% of these occurred between 8 and 27 days after shocking. Therefore, any study involving recapture of electrofished rainbow trout should occur within 7 days of the initial sampling period or the estimates could be severely biased. Future studies of electrofishing mortality to rainbow should be at least 30 days in length. This could be difficult in field experiments because other factors could affect survival of wild fish held in pens, such as the stress of crowding and inadequate water flow.

The high rate of mortality in shocked-injured fish (52%) could reflect mortality from spinal injury, but shocked-uninjured fish had 29% mortality and spinal injury was not determined in these fish. There was no significant difference between these mortality levels. This may indicate that other physiological effects caused by electroshocking are just as important a concern in causing mortality as spinal injury. A combination of physiological and environmental factors as a source of mortality in rainbow trout has been discussed in other literature (Schreck et al. 1976). Further study into other physiological injuries caused by electrofishing is necessary, but until these studies are conducted long-term mortality after electrofishing would be the best measure of the effects of an electrofishing waveform.

Electrofishing had no effect on growth in both the long-term mortality experiments (homogeneous and heterogeneous fields). The results could be different in a wild population, where an injury could influence a fish's ability to capture food.

In the field trials, results were variable for DC. Why the injury rates were variable is unclear. Fifty-five percent of the X-rays for DC in trial two were unreadable, but the unreadable X-rays should have occurred randomly and not highly biased the injury rate. Mortality rates were also variable for DC between the two trials. The low P value (0.1366) in the test comparing capture rates of DC and CPS™, suggest that the capture rate for DC would have been significantly higher, if sample size had been larger. CPS™ had the second lowest injury rate and lowest mortality rate, and appeared to have the least "stunning" power of the three waveforms (personal observation). Injury rate for DC in the second trial was similar to that for CPS™. In the first trial DC gave capture rates similar to the second trial, but unacceptable injury and mortality rates. PDC 25/75 had the highest injury and mortality rates and is clearly unacceptable for use on rainbow trout, though the capture rates were similar to DC. There was no difference in mean lengths of rainbow trout captured with DC or PDC 25/75, but fish captured with CPS™ were significantly larger than DC. This would indicate that CPS™ is biased towards capturing larger fish. The results of this experiment would lead to the use of CPS™ on rainbow trout, were it not for unacceptably low capture rate and tendency to capture larger fish. However, variable results in injury and mortality for DC, combined with the high capture rates, indicates a need for further testing of DC as a means to capture rainbow trout.

A recommendation from the results of these experiments would be further testing of the DC and CPS™ waveforms. Field trials comparing the two waveforms are necessary to: (1) determine actual injury rates of DC; (2) verify the high capture rates of DC and low capture rates of CPS™; (3) verify the low injury and mortality rates of CPS™ and low mortality of DC. Experiments designed to answer these questions should be conducted at a site that provides: (1) high density of rainbow trout, to allow for sample sizes of 70 fish or greater per waveform (90% level of confidence; Zar 1984); (2) a river segment sufficiently long to allow for at least 5 replicates per waveform with no repeatable passes, and progress upstream so the likelihood of capturing previously injured fish is low; and (3) a river system that has no history of electrofishing.

Fisheries biologists and workers must be concerned with the effects the method of collection has on the fish population and possible sampling bias to the results. In mark-recapture studies, concern of reduced catchability of fish in subsequent captures should not be overlooked (Cross and Stott 1975). If electrofishing is the method of capture, a waveform that has low injury and mortality rates is desired. In large rainbow trout, pulsed DC causes injury and mortality rates that could bias results and affect the fish population; DC and CPS™ may be acceptable alternatives, depending on study objectives and sampling requirements.

The results from the above experiments were conducted at lower water conductivities (30-121 μS/cm), and may not be applicable to systems with higher conductivity. The species that is sought should also be of concern to fisheries workers. Injury rates of 3-62%, (depending on river system) have been reported for Arctic grayling *Thymallus arcticus*, less than 5% spinal injury for least cisco *Coregonus sardinella*, and humpback whitefish *Coregonus pidschian*, and nearly 16% for northern pike *Esox lucius*, all captured with PDC 60/50 (Holmes et al. 1990). The variability in injury rates in species from a single waveform must be kept in mind when electrofishing in a system where many species exist. A waveform or method that will provide acceptable catch rates with the least injury to all species should be used.

Literature Cited

BMDP Statistical Software. 1990. BMDP Statistical Software, Manuals 1 and 2. University of California Press, Berkeley.

Bouck, Gerald R., and R.C. Ball. 1966. Influence of capture methods on blood characteristics and mortality in the rainbow trout (S. gairdneri). Trans. Am. Fish. Soc. 95:170-176.

Cross, D.G., and B. Stott. 1975. The effect of electric fishing on the subsequent capture of fish. J. Fish. Biol. 7:349-357.

Gatz, A.J.,Jr., J.M. Loar, and G.F. Cada. 1986. Effects of repeated electroshocking on instantaneous growth of trout. N. Am. J. Fish. Mgmt. 6:176-182.

Hauck, F.R. 1949. Some harmful effects of the electroshocker on large rainbow trout. Trans. Am. Fish. Soc. 77(1):61-64.

Holmes, R., D. McBride, T. Viavant, and J.B. Reynolds. 1990. Electrofishing induced mortality and injury to rainbow trout, Arctic grayling, humpback whitefish, least cisco and northern pike. Division of Sportfish, ADFG, Fishery Manuscript No. 90-3. 95 pgs.

Horak, D.L., and W.D. Klein. 1967. Influence of capture methods on fishing success, stamina, and mortality of rainbow trout (S. gairdneri) in Colorado. Trans. Am. Fish. Soc. 96:220-222.

Hudy, M. 1985. Rainbow trout and brook trout mortality from high voltage AC electrofishing in a controlled environment. N. Am. J. Fish. Mgmt. 5:475-479.

Kynard, B., and E. Lonsdale. 1975. Experimental study of galvanonarcosis for rainbow trout (S. gairdneri) immobilization. J. Fish. Res. Board Can. 32:300-302.

Maxfield, G.H., R.L. Lander, and K.L. Liscom. 1971. Survival, growth, and fecundity of hatchery-reared rainbow trout after exposure to pulsating direct current. Trans. Am. Fish. Soc. 100:546-552.

McCrimmon, H.R., and B. Bidgood. 1965. Abnormal vertebrae in the rainbow trout with particular reference to electrofishing. Trans. Am. Fish. Soc. 94:84-88.

Mesa, M.G., and C.B. Schreck. 1989. Electrofishing mark-recapture and depletion methodologies evoke behavioral and physiological changes in cutthroat trout. Trans. Am. Fish. Soc. 118:644-658.

Pratt, V.S. 1954. Fish mortality caused by electrical shockers. Trans. Am. Fish. Soc. 84:93-96.

SAS Institute Inc.. 1989. SAS Manual. SAS Institute Inc., Cary, North Carolina.

Schreck, C.B., R.A. Whaley, M.L. Bass, O.E. Maughan, and M. Solazzi. 1976. Physiological responses of rainbow trout (S. gairdneri) to electroshock. J. Fish. Res. Board Can. 33:76-84.

Sharber, N.G., and S.W. Carothers. 1988. Influence of electrofishing pulse shape on spinal injuries in adult rainbow trout. N. Am. J. Fish. Mgmt. 8:117-122.

Sullivan, C. 1956. The importance of size groupings in population estimates employing electric shockers. Prog. Fish-Culturist. 18:188-190.

Woodward, C.C., and R.J. Strange. 1987. Physiological stress responses in wild and hatchery-reared rainbow trout. Trans. Am. Fish. Soc. 116:574-579.

Zar, J.R. 1984. Biostatistical Analysis, second edition. Prentice-Hall, Inc., Englewood Cliffs, New Jersey.

Appendix

Appendix, Table 7. Waveform, voltage gradient, fork length, weight, and ratings for spinal injury and internal hemorrhage by fish for the homogeneous field experiment conducted June 27-29, July 19, 1990 and July 30, 1991 at the Fort Richardson Hatchery, Anchorage, Alaska. Water conductivity and temperature ranged from 100-121 S/cm and 9-13 C. LO=low voltage; HI=high voltage.

Waveform	Voltage gradient (V/cm)	Tag	Fork length (mm)	Weight (g)	Spinal injury	Internal hemorrhage
PDC 60/50-LO	0.39	204	424	940	2	3
PDC 60/50-LO	0.29	246	497	1660	2	3
PDC 60/50-LO	0.66	252	481	1280	2	1
PDC 60/50-LO	0.46	201	517	1300	2	0
PDC 60/50-LO	0.41	257	604	1680	2	0
PDC 60/50-LO	0.33	220	383	750	2	0
PDC 60/50-LO	0.27	258	437	1020	1	1
PDC 60/50-LO	0.31	243	445	1020	0	3
PDC 60/50-LO	0.30	238	456	1020	0	3
PDC 60/50-LO	0.35	255	487	1230	0	0
PDC 60/50-LO	0.33	249	532	1950	0	0
PDC 60/50-LO	0.27	205	478	1100	0	0
PDC 60/50-HI	2.41	208	443	1030	2	3

Appendix, Table 7 (continued)

Waveform	Voltage gradient (V/cm)	Tag	Fork length (mm)	Weight (g)	Spinal injury	Internal hemorrhage
PDC 60/50-HI	2.51	245	418	735	2	2
PDC 60/50-HI	2.90	247	629	2680	2	0
PDC 60/50-HI	2.76	213	484	1130	1	3
PDC 60/50-HI	2.94	235	438	1210	1	0
PDC 60/50-HI	1.00	251	416	800	0	3
PDC 60/50-HI	2.76	242	442	910	0	0
PDC 60/50-HI	2.57	225	489	1350	0	0
PDC 60/50-HI	2.57	244	453	1030	0	0
PDC 60/50-HI	2.31	207	477	1080	0	0
PDC 60/50-HI	2.00	210	438	1150	0	0
PDC 60/50-HI	1.98	250	429	980	0	0
DC-LO	0.68	332	411	840	2	3
DC-LO	0.63	297	424	630	2	2
DC-LO	0.34	337	417	840	2	1
DC-LO	0.32	340	420	900	2	0
DC-LO	0.30	324	500	1570	2	0
DC-LO	0.58	272	447	950	1	0
DC-LO	0.69	313	495	1320	0	2
DC-LO	0.33	326	466	1130	0	1
DC-LO	0.71	277	453	830	0	0

Appendix, Table 7 (continued)

Waveform	Voltage gradient (V/cm)	Tag	Fork length (mm)	Weight (g)	Spinal injury	Internal hemorrhage
DC-LO	0.67	328	433	950	0	0
DC-LO	0.67	280	474	1260	0	0
DC-LO	0.67	294	444	1180	0	0
DC-LO	0.56	318	528	1540	0	0
DC-LO	0.47	322	493	1320	0	0
DC-LO	0.45	335	462	1120	0	0
DC-LO	0.39	331	448	1050	0	0
DC-LO	0.38	333	441	1040	0	0
DC-LO	0.26	339	436	980	0	0
DC-HI	0.90	321	451	1020	2	2
DC-HI	1.24	287	507	1770	2	0
DC-HI	0.95	292	491	1580	2	0
DC-HI	1.02	281	460	1060	1	1
DC-HI	0.86	323	428	860	0	2
DC-HI	0.72	336	428	860	0	2
DC-HI	1.31	306	502	1570	0	1
DC-HI	1.30	299	496	1320	0	0
DC-HI	1.24	304	420	790	0	0
DC-HI	1.22	300	472	1170	0	0
DC-HI	0.92	312	438	980	0	0

Appendix, Table 7 (continued)

Waveform	Voltage gradient (V/cm)	Tag	Fork length (mm)	Weight (g)	Spinal injury	Internal hemorrhage
DC-HI	0.86	284	477	1400	0	0
DC-HI	0.77	309	513	1390	0	0
DC-HI	0.76	315	477	1210	0	0
DC-HI	0.76	273	469	1200	0	0
DC-HI	0.73	310	475	1280	0	0
DC-HI	0.72	276	528	1730	0	0
DC-HI	0.72	291	415	1000	0	0
CPS-LO	0.13	2483	386	590	2	N/A
CPS-LO	0.13	2496	406	690	1	1
CPS-LO	0.13	1752	443	870	0	3
CPS-LO	0.11	1776	430	850	0	3
CPS-LO	0.12	1758	408	720	0	2
CPS-LO	0.13	1788	378	600	0	0
CPS-LO	0.12	1755	394	610	0	0
CPS-LO	0.12	1756	412	660	0	0
CPS-LO	0.12	1797	418	800	0	0
CPS-LO	0.12	1760	443	910	0	0
CPS-LO	0.12	2482	404	660	0	0
CPS-LO	0.11	1710	427	810	0	0
CPS-HI	0.39	2492	408	770	2	3

Appendix, Table 7 (continued)

Waveform	Voltage gradient (V/cm)	Tag	Fork length (mm)	Weight (g)	Spinal injury	Internal hemorrhage
CPS-HI	0.39	1708	405	760	2	0
CPS-HI	0.4	2498	384	680	1	2
CPS-HI	0.4	1711	410	730	0	3
CPS-HI	0.39	1787	378	600	0	3
CPS-HI	0.39	1772	328	390	0	3
CPS-HI	0.39	1773	397	700	0	2
CPS-HI	0.65	1786	359	480	0	0
CPS-HI	0.55	1753	373	520	0	0
CPS-HI	0.39	1796	427	810	0	0
CPS-HI	0.38	1724	346	390	0	0
CPS-HI	0.36	1725	411	770	0	0
CONTROL	N/A	278	539	2020	1	0
CONTROL	N/A	226	625	2800	1	0
CONTROL	N/A	1759	358	480	0	3
CONTROL	N/A	266	423	830	0	0
CONTROL	N/A	223	545	1900	0	0
CONTROL	N/A	195	420	660	0	0
CONTROL	N/A	293	461	1130	0	0
CONTROL	N/A	342	401	680	0	0
CONTROL	N/A	301	474	1170	0	0

Appendix, Table 7 (continued)

Waveform	Voltage gradient (V/cm)	Tag	Fork length (mm)	Weight (g)	Spinal injury	Internal hemorrhage
CONTROL	N/A	216	443	1000	0	0
CONTROL	N/A	285	414	800	0	0
CONTROL	N/A	212	478	1270	0	0
CONTROL	N/A	254	449	1030	0	0
CONTROL	N/A	283	489	1400	0	0
CONTROL	N/A	197	528	1730	0	0
CONTROL	N/A	196	488	1100	0	0
CONTROL	N/A	262	446	960	0	0
CONTROL	N/A	305	425	930	0	0
CONTROL	N/A	307	493	1340	0	0
CONTROL	N/A	206	400	778	0	0
CONTROL	N/A	230	491	1160	0	0
CONTROL	N/A	316	480	1280	0	0
CONTROL	N/A	260	582	2320	0	0
CONTROL	N/A	264	420	720	0	0
CONTROL	N/A	198	460	1060	0	0
CONTROL	N/A	232	465	1250	0	0
CONTROL	N/A	231	496	1370	0	0
CONTROL	N/A	234	419	835	0	0
CONTROL	N/A	263	501	1750	0	0

Appendix, Table 7 (continued)

Waveform	Voltage gradient (V/cm)	Tag	Fork length (mm)	Weight (g)	Spinal injury	Internal hemorrhage
CONTROL	N/A	265	431	880	0	0
CONTROL	N/A	224	479	1290	0	0
CONTROL	N/A	271	480	1300	0	0
CONTROL	N/A	279	477	1150	0	0
CONTROL	N/A	219	539	1910	0	0
CONTROL	N/A	308	468	1130	0	0
CONTROL	N/A	217	468	1230	0	0
CONTROL	N/A	229	449	850	0	0
CONTROL	N/A	1761	329	320	0	0
CONTROL	N/A	1715	458	910	0	0
CONTROL	N/A	1716	339	440	0	0
CONTROL	N/A	1706	407	720	0	0
CONTROL	N/A	1707	429	780	0	0
CONTROL	N/A	1762	421	810	0	0
CONTROL	N/A	1798	423	770	0	0
CONTROL	N/A	1722	407	690	0	0
CONTROL	N/A	1754	392	720	0	0
CONTROL	N/A	1712	445	920	0	0
CONTROL	N/A	1717	381	650	0	0
CONTROL	N/A	1703	386	530	0	0

Appendix, Table 7 (continued)

Waveform	Voltage gradient (V/cm)	Tag	Fork length (mm)	Weight (g)	Spinal injury	Internal hemorrhage
CONTROL	N/A	1799	407	840	0	0
CONTROL	N/A	2500	378	470	0	0
CONTROL	N/A	2489	307	300	0	0
CONTROL	N/A	1789	349	480	0	0
CONTROL	N/A	1794	388	650	0	0
CONTROL	N/A	1795	439	900	0	0
CONTROL	N/A	1790	392	710	0	0
AC-LO	0.21	253	508	1670	2	3
AC-LO	0.20	256	459	990	2	1
AC-LO	0.29	233	384	700	2	0
AC-LO	0.22	214	529	1820	2	0
AC-LO	0.20	202	425	850	2	0
AC-LO	0.20	240	410	805	2	0
AC-LO	0.21	261	437	1020	1	3
AC-LO	0.24	211	510	1470	0	0
AC-LO	0.22	227	505	1900	0	0
AC-LO	0.20	241	400	640	0	0
AC-LO	0.20	239	468	1180	0	0
AC-LO	0.19	236	527	1230	0	0
AC-HI	3.46	222	544	2170	2	3

Appendix, Table 7 (continued)

Waveform	Voltage gradient (V/cm)	Tag	Fork length (mm)	Weight (g)	Spinal injury	Internal hemorrhage
AC-HI	3.24	228	485	1160	2	3
AC-HI	3.17	218	371	640	2	3
AC-HI	3.10	248	592	2420	2	3
AC-HI	4.50	199	414	760	2	0
AC-HI	3.31	209	450	1040	2	0
AC-HI	3.22	237	463	1120	2	0
AC-HI	2.71	221	519	1500	1	3
AC-HI	3.20	259	426	990	1	1
AC-HI	4.50	200	489	1350	0	2
AC-HI	3.50	203	467	1210	0	0
AC-HI	3.30	215	566	2170	0	0
PDC 30/75-LO	1.32	1781	405	680	2	3
PDC 30/75-LO	0.79	1800	416	850	2	3
PDC 30/75-LO	0.7	1793	436	840	2	3
PDC 30/75-LO	1.21	1784	415	730	2	2
PDC 30/75-LO	0.8	1757	360	500	2	0
PDC 30/75-LO	0.72	1785	397	670	0	3
PDC 30/75-LO	0.85	1723	391	630	0	2
PDC 30/75-LO	1.91	1777	372	510	0	1
PDC 30/75-LO	1.05	1744	432	900	0	0

Appendix, Table 7 (continued)

Waveform	Voltage gradient (V/cm)	Tag	Fork length (mm)	Weight (g)	Spinal injury	Internal hemorrhage
PDC 30/75-LO	0.73	1782	349	510	0	0
PDC 30/75-LO	0.71	1713	413	720	0	0
PDC 30/75-LO	0.71	1718	430	880	0	0
PDC 30/75-HI	3.34	1768	414	700	2	3
PDC 30/75-HI	3.21	1775	439	950	2	3
PDC 30/75-HI	3.35	1714	399	730	2	2
PDC 30/75-HI	3.38	1764	438	920	2	0
PDC 30/75-HI	3.26	1709	345	480	2	0
PDC 30/75-HI	3.36	1766	400	700	0	1
PDC 30/75-HI	4.7	1750	403	740	0	0
PDC 30/75-HI	3.43	1791	368	500	0	0
PDC 30/75-HI	3.4	1769	390	610	0	0
PDC 30/75-HI	3.34	1770	391	550	0	0
PDC 30/75-HI	3.34	1765	408	700	0	0
PDC 30/75-HI	3.29	1783	395	630	0	0
PDC 30/50-LO	2.42	1742	411	830	2	3
PDC 30/50-LO	0.52	1702	549	980	2	3
PDC 30/50-LO	0.62	1735	420	810	2	1
PDC 30/50-LO	0.47	1701	394	660	2	0
PDC 30/50-LO	0.56	1771	408	690	1	3

Appendix, Table 7 (continued)

Waveform	Voltage gradient (V/cm)	Tag	Fork length (mm)	Weight (g)	Spinal injury	Internal hemorrhage
PDC 30/50-LO	0.57	1763	350	450	1	0
PDC 30/50-LO	0.45	1719	394	690	1	0
PDC 30/50-LO	0.48	1720	445	900	0	1
PDC 30/50-LO	0.64	1778	358	510	0	0
PDC 30/50-LO	0.62	1779	405	670	0	0
PDC 30/50-LO	0.54	1774	397	660	0	0
PDC 30/50-LO	0.48	1721	383	600	0	0
PDC 30/50-HI	2.33	2491	396	700	2	3
PDC 30/50-HI	2.32	2493	352	460	2	3
PDC 30/50-HI	2.27	2499	427	880	2	3
PDC 30/50-HI	2.15	1704	369	600	1	3
PDC 30/50-HI	2.26	1780	357	480	0	2
PDC 30/50-HI	2.16	1751	379	600	0	2
PDC 30/50-HI	3.18	1739	349	440	0	0
PDC 30/50-HI	3.18	1792	374	590	0	0
PDC 30/50-HI	2.31	2479	385	590	0	0
PDC 30/50-HI	2.31	2490	425	780	0	0
PDC 30/50-HI	2.27	1767	412	680	0	0
PDC 30/50-HI	2.21	1705	414	680	0	0

Appendix, Table 8. Waveform, reaction, stun, and maximum voltage gradient, fork length, weight, spinal injury rating, and date of death by fish for the heterogeneous field experiment conducted August 1, 1991 at the Fort Richardson Hatchery, Anchorage, Alaska. Fish were exposed to 200V, 4.5A and 400V, 10A (CPS only). Water conductivity and temperature were 103 S/cm at 11 C.

Waveform	Tag	Initial size length (mm)	Initial size weight (g)	Spinal injury	Date of death	Voltage gradient (V/cm) reaction	Voltage gradient (V/cm) stun	Voltage gradient (V/cm) max	Final size length (mm)	Final size weight (g)
PDC 60/50	2435	357	500	2		0.485	3.180	3.180		
PDC 60/50	2440	405	710	2		0.093	0.903	0.903	431	1030
PDC 60/50	2426	361	440	2		0.131	1.675	1.979		
PDC 60/50	2433	470	1070	2		0.101	0.330	2.470	459	800
PDC 60/50	2448	419	740	2		0.178	1.675	3.079		
PDC 60/50	2439	409	720	2		0.054	1.675	3.079	454	1140
PDC 60/50	2432	317	480	2	08/05	0.178	1.675	2.776		
PDC 60/50	2436	386	620	1		0.201	0.512	3.174		
PDC 60/50	2450	379	550	0		0.254	1.756	1.946	423	840
PDC 60/50	2449	418	740	0		0.147	0.307	2.470		
PDC 60/50	2430	382	520	0		0.078	1.675	3.079		
PDC 60/50	2434	370	530	0		0.177	1.126	3.079		
PDC 30/50	2441	444	1040	2	08/05	0.355	0.918	3.808		
PDC 30/50	2437	361	440	2		0.327	1.771	6.140	392	680
PDC 30/50	2470	402	660	2		0.073	1.691	3.134		
PDC 30/50	2472	371	510	2	08/17	0.272	1.432	2.679		
PDC 30/50	2429	375	510	0		0.083	1.691	2.566		
PDC 30/50	2446	382	540	0		0.106	1.796	5.270		
PDC 30/50	2445	419	700	0		0.124	1.432	4.640	465	1200

Appendix, Table 8 (continued)

Waveform	Tag	Initial size length (mm)	Initial size weight (g)	Spinal injury	Date of death	Voltage gradient (V/cm) reaction	Voltage gradient (V/cm) stun	Voltage gradient (V/cm) max	Final size length (mm)	Final size weight (g)
PDC 30/50	2427	431	770	0		0.248	3.134	6.020		
PDC 30/50	2444	408	670	0		0.116	2.814	6.020	454	1120
PDC 30/50	2442	397	580	0		0.165	0.458	2.770	434	1100
PDC 30/50	2447	427	830	0		0.199	3.233	3.233	469	1270
PDC 30/50	2431	363	440	0	NO DAT	0.092	1.098	6.020		
PDC 20/75	2457	508	1220	2		0.156	3.436	6.400	514	1420
PDC 20/75	2456	338	440	2		0.130	3.436	3.436		
PDC 20/75	2474	542	1630	2	08/22	0.136	7.830	7.830		
PDC 20/75	2461	437	870	0	08/17	0.112	2.143	3.206		
PDC 20/75	2462	388	530	0		0.374	0.688	4.918		
PDC 20/75	2464	437	820	0		0.230	0.399	6.400	447	850
PDC 20/75	2454	438	790	0		0.152	0.448	7.830	470	1250
PDC 20/75	2451	416	680	0		0.156	0.470	7.570	450	1010
PDC 20/75	2460	378	500	0		0.130	0.436	4.918		
PDC 20/75	2475	366	460	0		0.256	3.760	7.100		
PDC 20/75	2465	376	460	0		0.328	3.760	7.830		
PDC 20/75	2473	422	740	0		0.374	0.688	2.432	455	1120
PDC 20/25	2471	419	800	2		0.058	0.710	1.253	410	850
PDC 20/25	2459	330	400	2	08/12	0.068	0.375	0.375		
PDC 20/25	2469	391	660	2		0.056	0.785	2.000	430	1130
PDC 20/25	2458	398	660	2		0.106	1.253	1.253		
PDC 20/25	2497	425	800	2	08/03	0.048	0.433	1.797		
PDC 20/25	2453	477	1050	2	08/22	0.082	0.710	2.340		
PDC 20/25	2466	343	420	1		0.090	0.361	1.710		

Appendix, Table 8 (continued)

Waveform	Tag	Initial size length (mm)	Initial size weight (g)	Spinal injury	Date of death	Voltage gradient (V/cm) reaction	Voltage gradient (V/cm) stun	Voltage gradient (V/cm) max	Final size length (mm)	Final size weight (g)
PDC 20/25	2468	435	870	0		0.053	1.253	1.797	474	1330
PDC 20/25	2452	434	760	0		0.102	0.426	2.340	438	890
PDC 20/25	2463	390	610	0		0.068	0.217	1.422		
PDC 20/25	2467	390	530	0		0.053	0.117	0.117	435	900
PDC 20/25	2455	431	790	0		0.108	0.119	2.000	434	870
DC	2476	422	760	2		N/A	N/A	N/A	445	1050
DC	2487	400	620	1		0.563	5.463	5.463	427	910
DC	2478	445	830	0		0.460	3.290	10.600	484	1360
DC	2486	420	710	0		0.436	6.064	10.600	460	1090
DC	2481	386	570	0		0.184	5.606	10.600	433	910
DC	2484	425	710	0		0.264	0.438	7.807	414	600
DC	2494	436	830	0		0.239	6.064	11.450	477	1250
DC	2477	389	540	0		0.476	6.436	12.350	444	1030
DC	2485	341	380	0		0.436	5.888	5.888		
DC	2488	371	450	0		0.415	5.524	10.560	384	570
DC	2495	374	510	0		0.387	1.792	5.651	399	670
DC	2480	394	550	0		0.228	1.891	8.126		
CPS	2401	404	720	2		0.020	0.309	0.309	421	910
CPS	2412	333	340	0		0.016	0.175	0.320	369	590
CPS	2421	386	590	0		0.028	0.036	0.562		
CPS	2406	420	710	0	NO DAT	0.019	0.043	0.519		
CPS	2405	377	540	0		0.011	0.289	0.431	385	650
CPS	2411	332	390	0		0.025	0.108	0.401		
CPS	2423	462	910	0		0.023	0.165	0.534	479	1220

Appendix, Table 8 (continued)

Waveform	Tag	Initial size length (mm)	Initial size weight (g)	Spinal injury	Date of death	Voltage gradient (V/cm) reaction	Voltage gradient (V/cm) stun	Voltage gradient (V/cm) max	Final size length (mm)	Final size weight (g)
CPS	2403	358	490	0		0.017	0.280	0.519		
CPS	2410	305	390	0		N/A	N/A	N/A	359	530
CPS	2419	411	620	0		0.015	0.170	0.218		
CPS	2416	406	660	0		0.029	0.411	0.534		
CPS	2413	386	580	0		0.033	0.280	0.519		

Appendix, Table 9. Waveform, voltage gradient, fork length, weight, spinal injury rating, and mortality by fish for the long-term mortality experiment initiated July 9-10, 1991 at the Fort Richardson Hatchery, Anchorage, Alaska. Fish were exposed to 250V of PDC 60/50 for 5 seconds. Water conductivity ranged from 95-104 S/cm and 10-12 C.

Treatment S=shocked C=control	Voltage gradient (V/cm)	Tag	Initial size length (mm)	Initial size weight (g)	Spinal injury	Mortality 0=no 1=yes	Final size length (mm)	Final size weight (g)
S	2.43	1668	398	700	3	0		
S	2.11	1740	415	800	2	0		
S	1.97	1691	314	360	2	0	357	670
S	2.45	1672	381	590	2	0		
S	2.46	1665	388	670	2	0		
S	2.42	1661	442	870	2	1		
S	2.33	1660	467	960	2	0	521	1740
S	2.44	1652	379	560	2	1		
S	2.27	1650	430	850	2	0		
S	2.19	1649	449	1080	2	0		
S	2.24	1648	397	680	2	1		
S	2.44	1643	453	990	2	1		
S	2.19	1642	322	380	2	0		
S	1.99	1640	382	560	2	1		

Appendix, Table 9 (continued)

Treatment S=shocked C=control	Voltage gradient (V/cm)	Tag	Initial size length (mm)	Initial size weight (g)	Spinal injury	Mortality 0=no 1=yes	Final size length (mm)	Final size weight (g)
S	2.42	1637	439	890	2	1		
S	2.29	1635	482	1250	2	1		
S	2.46	1632	388	620	2	1		
S	2.31	1601	370	480	2	1		
S	2.46	1498	386	560	2	1		
S	2.18	1452	374	590	2	0	405	850
S	2.29	1736	412	660	1	1		
S	2.23	1700	385	560	1	1		
S	2.25	1653	406	680	1	0		
S	2.41	1647	539	1490	1	0		
S	2.19	1633	394	620	1	0	383	550
S	2.21	1617	405	670	1	0		
S	2.24	1611	400	610	1	1		
S	2.19	1746	426	740	0	1		
S	2.11	1741	376	460	0	0	406	760
S	1.87	1737	404	660	0	0	445	1020
S	2.26	1733	415	680	0	1		
S	2.26	1732	389	580	0	1		
S	1.84	1728	362	460	0	0		
S	1.89	1727	430	770	0	0	467	1100

Appendix, Table 9 (continued)

Treatment S=shocked C=control	Voltage gradient (V/cm)	Tag	Initial size length (mm)	Initial size weight (g)	Spinal injury	Mortality 0=no 1=yes	Final size length (mm)	Final size weight (g)
S	2.05	1726	403	620	0	0		
S	2.35	1699	374	500	0	0	377	460
S	2.32	1695	400	570	0	1		
S	2.22	1694	404	730	0	1		
S	2.27	1693	396	610	0	0	448	1060
S	2.20	1692	492	1020	0	0	504	1280
S	2.31	1689	378	520	0	0		
S	2.35	1687	381	490	0	0		
S	2.34	1686	397	590	0	1		
S	2.28	1685	393	550	0	1		
S	2.33	1684	373	490	0	0		
S	2.30	1683	422	770	0	1		
S	2.36	1681	412	720	0	0	430	900
S	2.33	1679	329	450	0	1		
S	2.16	1678	364	460	0	0	410	820
S	2.17	1677	462	1000	0	0		
S	2.28	1676	335	370	0	0	387	700
S	2.46	1675	342	500	0	0		
S	2.37	1674	427	800	0	1		
S	2.41	1671	365	440	0	0		

Appendix, Table 9 (continued)

Treatment S=shocked C=control	Voltage gradient (V/cm)	Tag	Initial size length (mm)	Initial size weight (g)	Spinal injury	Mortality 0=no 1=yes	Final size length (mm)	Final size weight (g)
S	2.48	1667	389	550	0	0		
S	2.30	1663	404	600	0	0		
S	2.24	1662	339	370	0	0	363	560
S	2.52	1657	447	820	0	1		
S	2.43	1656	346	360	0	0	392	710
S	2.31	1655	389	530	0	0	451	1070
S	2.53	1654	470	980	0	1		
S	2.29	1646	420	630	0	0	456	1120
S	2.29	1645	382	520	0	0	424	890
S	2.26	1636	347	370	0	0	398	840
S	2.37	1634	367	550	0	1		
S	2.24	1628	364	460	0	0		
S	2.35	1626	338	380	0	0		
S	2.32	1625	364	440	0	0	391	680
S	2.25	1624	383	490	0	0	435	850
S	2.22	1623	390	500	0	0	414	790
S	2.08	1619	358	440	0	0		
S	2.22	1618	358	450	0	1		
S	2.24	1616	373	580	0	0		
S	2.12	1612	417	650	0	0		

Appendix, Table 9 (continued)

Treatment S=shocked C=control	Voltage gradient (V/cm)	Tag	Initial size length (mm)	Initial size weight (g)	Spinal injury	Mortality 0=no 1=yes	Final size length (mm)	Final size weight (g)
S	2.26	1610	328	370	0	0	383	700
S	2.02	1609	415	730	0	0	457	1120
S	2.28	1608	405	650	0	0		
S	2.15	1607	396	530	0	0	453	1040
S	2.36	1604	405	650	0	0		
S	2.19	1603	362	420	0	0	400	700
S	2.13	1602	329	350	0	0		
S	2.50	1500	364	480	0	1		
S	2.52	1499	469	1140	0	0	490	1470
S	2.33	1496	316	370	0	1		
S	2.20	1491	434	820	0	0	471	1270
S	2.40	1489	397	630	0	0	437	940
S	2.52	1488	361	520	0	0		
S	2.15	1487	438	800	0	0	494	1380
S	2.56	1486	384	630	0	1		
S	2.30	1485	390	620	0	0	467	1210
S	2.52	1484	382	570	0	0	408	840
S	2.42	1483	415	740	0	1		
S	2.54	1482	345	430	0	1		
S	2.52	1481	468	1100	0	0	526	1810

Appendix, Table 9 (continued)

Treatment S=shocked C=control	Voltage gradient (V/cm)	Tag	Initial size length (mm)	Initial size weight (g)	Spinal injury	Mortality 0=no 1=yes	Final size length (mm)	Final size weight (g)
S	2.39	1479	374	520	0	0	419	930
S	2.56	1478	427	880	0	1		
S	2.40	1477	367	500	0	0	426	880
S	2.50	1476	382	520	0	0	408	860
S	2.58	1470	449	940	0	0	505	1610
S	2.44	1469	395	520	0	1		
S	2.53	1457	394	590	0	0	471	1140
S	2.56	1454	409	600	0	0	442	1000
C	N/A	1627	385	570	1	0		
C	N/A	1749	415	680	0	0	466	1220
C	N/A	1748	380	570	0	0	426	900
C	N/A	1747	433	750	0	0	461	1100
C	N/A	1745	399	590	0	0	402	670
C	N/A	1743	435	770	0	0	438	840
C	N/A	1738	348	460	0	0		
C	N/A	1734	403	580	0	0	429	850
C	N/A	1731	383	590	0	0		
C	N/A	1730	361	480	0	0		
C	N/A	1729	401	530	0	0	424	890
C	N/A	1698	347	430	0	0		

Appendix, Table 9 (continued)

Treatment S=shocked C=control	Voltage gradient (V/cm)	Tag	Initial size length (mm)	Initial size weight (g)	Spinal injury	Mortality 0=no 1=yes	Final size length (mm)	Final size weight (g)
C	N/A	1697	388	550	0	0		
C	N/A	1696	348	430	0	0		
C	N/A	1690	308	300	0	0		
C	N/A	1688	388	580	0	0	434	980
C	N/A	1682	385	540	0	0		
C	N/A	1680	390	580	0	0		
C	N/A	1673	358	440	0	1	407	700
C	N/A	1670	342	420	0	0		
C	N/A	1669	461	1020	0	0		
C	N/A	1666	438	730	0	0		
C	N/A	1664	384	580	0	1		
C	N/A	1659	395	660	0	0		
C	N/A	1658	414	730	0	1		
C	N/A	1651	342	440	0	0		
C	N/A	1644	314	300	0	0		
C	N/A	1641	393	500	0	0	428	850
C	N/A	1639	360	390	0	0		
C	N/A	1638	381	590	0	0		
C	N/A	1631	358	500	0	0		
C	N/A	1630	420	790	0	0		

Appendix, Table 9 (continued)

Treatment S=shocked C=control	Voltage gradient (V/cm)	Tag	Initial size length (mm)	Initial size weight (g)	Spinal injury	Mortality 0=no 1=yes	Final size length (mm)	Final size weight (g)
C	N/A	1629	335	360	0	0		
C	N/A	1622	412	710	0	0		
C	N/A	1621	424	730	0	0		
C	N/A	1620	381	550	0	0		
C	N/A	1615	445	830	0	0		
C	N/A	1614	360	450	0	0	392	760
C	N/A	1613	338	370	0	0		
C	N/A	1606	377	500	0	0	431	920
C	N/A	1605	383	560	0	0	434	990
C	N/A	1497	309	310	0	1		
C	N/A	1495	399	690	0	1		
C	N/A	1494	456	940	0	0	509	1520
C	N/A	1493	487	1210	0	0		
C	N/A	1492	366	390	0	0		
C	N/A	1490	371	540	0	1		
C	N/A	1480	339	390	0	0		
C	N/A	1475	428	730	0	0	487	1310
C	N/A	1474	403	550	0	0		

Appendix, Table 10. Waveform, fork length, date of mortality, spinal injury rating by fish for the field trial experiments conducted September 24-25, 1991 at Lake Creek, Alaska. Water conductivity was 30 S/cm at 7 C. DC-1=trial one; DC-2=trial two.

Waveform	Tag	Fork length (mm)	Date of death	Spinal Injury
DC-1	310379	351		0
DC-1	310307	366		2
DC-1	310382	312		2
DC-1	310381	368	09/28	2
DC-1	310380	332		1
DC-1	310081	296		0
DC-1	310383	371		0
DC-1	310388	350		0
DC-1	310389	255		2
DC-1	310393	262	09/25	0
DC-1	310394	338		0
DC-1	310395	301		0
DC-1	310398	237		2

Appendix, Table 10 (continued)

Waveform	Tag	Fork length (mm)	Date of death	Spinal Injury
DC-1	310399	342		0
DC-1	310400	332		2
DC-1	310401	351		2
DC-1	310402	239		0
DC-1	310403	403		N/A
CPS	310376	415		2
CPS	310377	433		0
CPS	310378	386		0
CPS	310391	369		0
CPS	310390	474		0
CPS	310392	310		0
CPS	310396	402		0
CPS	310397	371		0
DC-2	310410	244		0
DC-2	310415	314		N/A
DC-2	310416	469		0
DC-2	310417	447		0
DC-2	309215	375		0
DC-2	310418	373		N/A
DC-2	310419	274		0

Appendix, Table 10 (continued)

Waveform	Tag	Fork length (mm)	Date of death	Spinal Injury
DC-2	310420	329		0
DC-2	310421	300		N/A
DC-2	310422	306		N/A
DC-2	310423	320		N/A
DC-2	310424	255		N/A
DC-2	310188	357		0
DC-2	310425	240		N/A
DC-2	310426	257		0
DC-2	310427	492		0
DC-2	310429	261		0
DC-2	310430	328		0
DC-2	310431	325		0
DC-2	310432	274		0
DC-2	310433	402		N/A
DC-2	310434	434		0
DC-2	310435	363		N/A
DC-2	310262	467		0
DC-2	310441	393		N/A
DC-2	310442	314		N/A
DC-2*	310445	298		2

Appendix, Table 10 (continued)

Waveform	Tag	Fork length (mm)	Date of death	Spinal Injury
DC-2*	310446	278		1
DC-2*	310447	344		0
DC-2*	310448	250		0
DC-2*	310449	298		0
DC-2*	310451	401	09/30	2
DC-2*	310452	358		1
PDC 20/75	310404	324	09/25	N/A
PDC 20/75	310405	303		N/A
PDC 20/75	310406	504		0
PDC 20/75	310407	361		1
PDC 20/75	310408	278		0
PDC 20/75	310409	402		1
PDC 20/75	310411	436	09/28	N/A
PDC 20/75	310412	378		2
PDC 20/75	310413	349		2
PDC 20/75	310414	395		N/A
PDC 20/75	310428	506		N/A
PDC 20/75	310436	272	10/01	N/A
PDC 20/75	310437	395		0
PDC 20/75	310126	280		N/A

Appendix, Table 10 (continued)

Waveform	Tag	Fork length (mm)	Date of death	Spinal Injury
PDC 20/75	310438	303		N/A
PDC 20/75	310439	292		N/A
PDC 20/75	310440	253		N/A
PDC 20/75*	310443	348		1
PDC 20/75*	310444	385		0
PDC 20/75*	310450	335		2

* indicates fish captured day 3